ORCHARDING

BY

VICTOR RAY GARDNER

FREDERICK CHARLES BRADFORD

Of the Department of Horticulture of Michigan State College

AND

HENRY DAGGETT HOOKER

Of the Department of Horticulture of the University of Missouri

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PREFACE

Fruit growing is both an art and an industry. It is based on a body of abiding scientific facts and principles; some of these must remain basic so long as there is any fruit growing, and some are applicable only as economic conditions determine. The accelerating trend of the industry from farm-orchard production to highly specialized enterprises makes all the more imperative keen discrimination between what is good science and what is good business, between what is fundamentally far-sighted policy and what is temporarily expedient, and the relative rapidity of economic changes necessitates frequent reappraisal of various standard practices.

Future success and leadership in the industry will increasingly require more than a knowledge, however thorough, of the accepted current orchard practices. New discoveries must be weighed carefully; a change in one practice may enhance or diminish the importance of some other. Fluctuation in prices or in wages may render a good practice or good plant material unprofitable, or it may revive the applicability of an obsolete practice or the usefulness of discarded plant material. The enduring nature of an orchard investment places special impottance on foresight and renders mistakes particularly unfortunate. The leader, be he producer, teacher, or investigator, must be sensitive to changing conditions in many fields and must understand their ultimate effects on fruit growing; he must appreciate the difference between the unchanging and the transitory truths; he must assimilate the experience of the past; in short, he must know far more than is required in the daily routine of the orchard.

The work now offered is intended for beginners in the study of fruit growing. It was written in the belief that a rather comprehensive view of the whole field facilitates further acquirement for those who later consider the subject in detail and at the same time provides the most useful treatment of the subject for those whose chief interest will lie in other fields. In accordance with this view, effort has been made to present a sketch of the func-

tioning of fruit trees and an outline of the methods and problems of the fruit industry.

No empirical work, however authoritative, can fit perfectly more than a small portion of the United States, and for single states rather bulky volumes would sometimes be necessary. Details of regional requirements, applications, and practices must always be settled in the light of local experience. In the classroom, proper presentation of foundation principles has left scant time for local adaptation, other than by assigned reading, always inconvenient and frequently ill fitting. The present work is intended to supply material of wide applicability in convenient form, permitting a reversal of the usual procedure and placing on the student the chief responsibility for the fundamentals and on the instructor that for local practices. This, of course, virtually necessitates recourse to the professional school method of making reading assignments precede classroom treatment of most subjects.

Adherence to the order of presentation laid down is not essential. Duplications and repetitions have been made freely, partly to facilitate changes in presentation and to avoid cross-reference, always odious to the beginner.

The authors wish to acknowledge the assistance received from many sources in the preparation of this work. In particular are they indebted to Mr. W. C. Dutton and Dr. J. W. Crist, of the Michigan Agricultural Experiment Station, for their criticisms on portions of the manuscript and to Mr. B. G. Sitton, of the same station, for microscope preparations from which Figures 4, 7, 10, and 12 were made. Thanks are due to Dr. J. K. Shaw, of the Massachusetts Agricultural College, for Figure 55; to Prof. C. E. Schuster, of the Oregon Agricultural College, for Figures 132 and 133; to Prof. H. P. Barss, of the same institution, for Figures 98 and 102; to Mr. G. L. Philp, of the California Experiment Station, for Figure 19; to Mr. H. A. Cardinell, of the Michigan State College, for Figures 51 and 96; and to the Department of Horticulture of the University of Missouri for Figures 97 and 99. Figure 1 is reprinted from the Smith-Overton Textbook of General Botany with the permission of the publishers, the Macmillan Company. Figure 3 is reprinted by permission from "Textbook of General Botany" by R. M. Holman and W. W. Robbins, published by John Wiley & Sons, Inc. Figure 13 is from Sinnott's "Botany,

Principles and Problems," and Figures 2, 11, and 14 from Eames and MacDaniels' "Introduction to Plant Anatomy," both published by the McGraw-Hill Book Company, Inc. Figures 94, 95, 100, 101, 103, 104, 111, 112, 113, 114, 116, 126, and 128 are from the files of the Botanical Department, and Figures 92 93, 105, 106, 107, 108, 115, 117, 118, 119, 120, 121, 122, 123, and 124 are from the files of the Entomological Department, of the Michigan Agricultural Experiment Station. Most of the other figures are from the files of the Horticultural Department of the same station; some of them were made by Messrs. W. C. Dutton, H. P. Gaston, and R. E. Marshall; the rest by the authors. To Director R. S. Shaw of the Michigan Station, thanks are due for permission to use these illustrations.

THE AUTHORS.

EAST LANSING, MICH.
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CHAPTER I

TREE STRUCTURE

Though many orchardists succeed at fruit growing despite an almost complete ignorance of the ways in which fruit trees function, occasions arise when some knowledge of the anatomy and physiology of the trees would enable them to be still more successful. The fruit grower must, from time to time, himself be physician for his trees, with this difference from the medical practitioner: he must hunt out the sick, he must do all the symptom finding, he must pay the bills for the treatments he prescribes and he must take the responsibility of deciding whether the patient is worth saving. He may, in addition, function as surgeon for his trees. Like the physician, he will understand his patient better, in sickness as in health, if he knows its anatomy and physiology.

The orchardist can plant a tree in a favorable location, protect it from many insects and fungi, and keep its environment generally favorable; he can even feed it, but withal the tree must do much for itself. It must absorb moisture and nutrients through its roots, conduct them to the leaves and distribute the elaborated food from the leaves; it must grow, it must protect the various conducting and growth zones from desiccation and decay, it must store foods over winter for growth renewal in the spring, it must support its framework against wind and it must repair injuries. These various requirements are fulfilled by various more or less specialized tissues; to some ends numerous tissues contribute and some tissues perform more than one duty.

THE CELL IS THE STRUCTURAL UNIT

Since the way in which the tree functions depends on its structure, anatomy and function may be considered jointly, as each throws light on the other. Though the plant's larger

structural units are its various organs—the leaves, roots, stems, and flowers—close examination shows that each of these organs is composed of a number of different tissues. Examination with a microscope shows that all plant tissues are in turn made up of cells, which may be regarded as the structural units of the plant. These, though they are all small, vary greatly in size and shape

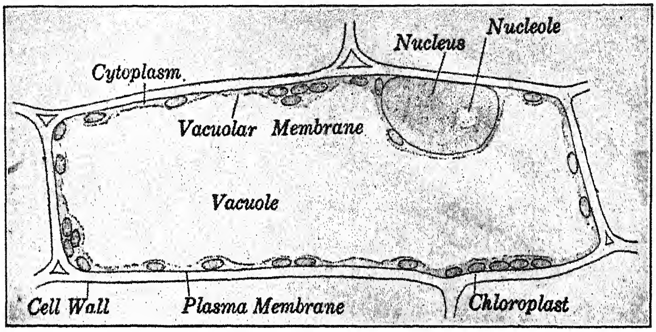


FIG. 1.—A single cell, showing characteristic structure. (*After Smith and Overton.*)

and in the way in which they are combined. In some tissues they are arranged loosely, with air spaces between them, like rocks in a stone fence; in others they are compressed, so that they fit exactly without intervening spaces, like bricks in a wall.

All plant cells have certain characteristics in common. On the outside is a hollow shell or wall that serves as a protective casing for the substances and structures within (Fig. 1). Young, newly formed cells have thin, pliable walls through which water and materials in solution pass readily. As they grow older, the wall is, in many cases, thickened and strengthened, a process that becomes evident in the gradually increasing "woodiness" of many mature tissues. This thickening usually interferes with the passage of solutions, but in many kinds of cells the walls remain thin at various points, forming so-called pits through which solutions pass readily from one cell to another (Fig. 2).

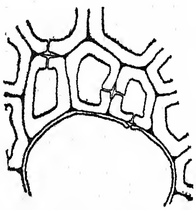


FIG. 2.—Bordered pits in wood cells of apple. (*After Eames and MacDaniels.*)

Enclosed by the cell wall is the living semi-liquid substance called protoplasm which fills young cells almost completely.

This living protoplasm is composed of several parts—a nucleus, a number of plastids, and the cytoplasm. The nucleus is a particularly dense portion of the protoplasm, usually more or less globular in shape, which takes an important part in the growth processes of the cell. The plastids are small bodies of various shapes and sizes. Some are packed with starch; in this case they are known as starch grains. Many are saturated with chlorophyll, the green coloring matter of plants. In still other cases they may be yellow, red, or orange, giving rise to some of the bright colors of flowers, leaves, and fruits. The rest of the protoplasm in which the nucleus and plastids float is the cytoplasm, a fluid substance in constant movement, streaming back and forth within the cell walls. In every cell as it grows older and larger, one or more "bubbles," known as vacuoles, appear in the cytoplasm; these are filled with cell sap. In due course they grow larger, unite, and eventually form a large central vacuole that occupies most of the cell, forcing the cytoplasm with the imbedded nucleus and plastids against the cell wall where it forms a thin lining, separating wall from vacuole (Fig. 1).

Cells have peculiarities which, in many cases, permit their identification by species and by function. Unusually thick walls and small cell cavity generally characterize the cell whose chief function is mechanical support. Cells which serve for conducting fluids, on the other hand, have large central cavities and numerous openings.

THE MAIN PLANT STRUCTURES

The main vegetative structures found in practically all higher plants are roots, stems, and leaves. The relative prominence of these parts varies with the species; in the strawberry, the stem constitutes such a relatively small part of the plant that it is occasionally referred to as stemless, while in asparagus, the leaves are reduced to mere bracts hardly recognizable as leaves. All fruit plants possess these three main parts, however, each with its characteristic function.

THE ROOT

The root is primarily an organ for the absorption of water and nutrients and secondarily an anchor that holds the plant in place. It also serves to some extent as a storage organ for surplus food materials, a function highly developed in plants with fleshy roots.

Many kinds of trees sometimes develop long fibrous streamer-like roots in tile drains; these are almost exclusively absorbing organs. Most roots, however, serve both purposes at the same time. Which function is performed better depends on conditions. In a rich soil with a high water table, the root system may suffice to keep the tree growing vigorously without protecting it against uprooting in high wind; in sandy soils the tree's anchorage may be proof against any storm, but the growth may be slow.

Practically all absorption takes place through the outermost or epidermal layer of cells near the ends of the new feeding rootlets and root fibers and through hair-like outgrowths from them, the so-called root hairs. These root hairs penetrate between the particles of soil and fasten themselves to the particles, greatly increasing the volume of soil with which an intimate contact is established (Fig. 3). As the tip of the rootlet grows ahead, the older root hairs gradually die and usually the whole epidermis also, leaving a corky, impervious layer of cells in contact with the soil. The older roots serve only as anchors and as channels for conducting water and nutrient materials to the above-ground parts of the tree and also for the transport of foods from the top of the tree to its root tips. The loss of young roots that accompanies even the most careful work may prove fatal to a tree transplanted while in leaf, though it is set into saturated soil, since the larger roots have lost most of their absorbing power. Likewise, deep cultivation, destroying a large part of the feeding rootlets that lie close to the surface of the soil, is frequently very injurious, especially at critical periods such as the time of fruit setting, though equally deep plowing or disking a few weeks earlier, when absorption and transpiration are less active, does no appreciable harm.

The water and nutrients absorbed by the rootlets and root hairs are carried up to the rest of the plant through elongated thick-walled cells arranged in strands called vascular bundles. These bundles not only serve as a system of pipes for the transport of water and nutrients, but they also give the root strength for anchorage and their arrangement in the interior of the root serves best to withstand the pull on the anchor (Fig. 4).

Roots increase in length and penetrate the soil by the enlargement and division of the cells at the tip, which is covered by a characteristic cap-like structure known as the root cap. This cap is pushed into the soil by the growth taking place just

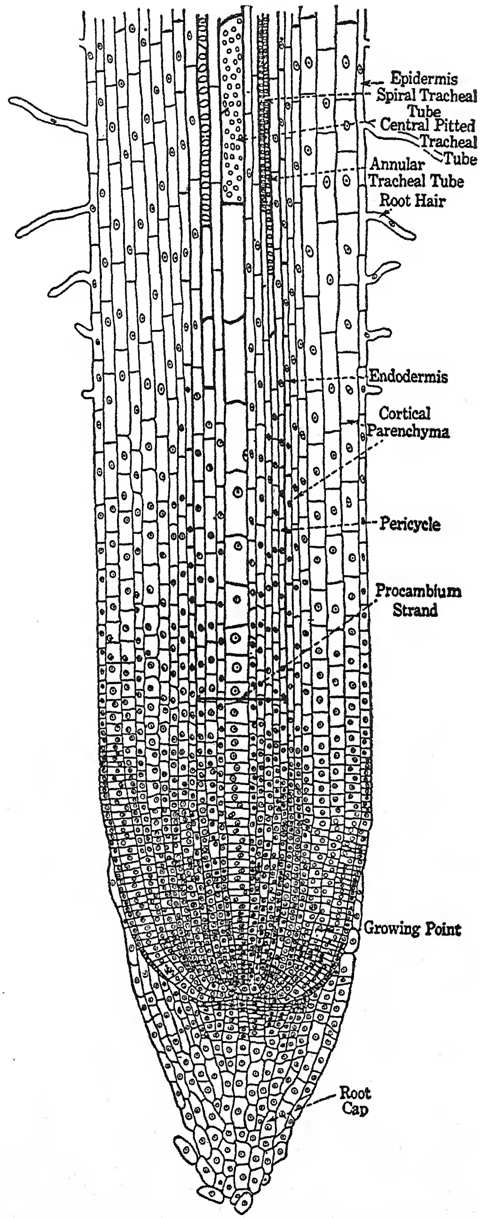


FIG. 3—The end of a rapidly growing root. (*After Holman and Robbins.*)

behind it, thus serving as a buffer for the tender tissues of the growing point that it protects. Unlike stems, roots of most plants have no definite system of branching, though in some species the branches often originate in rows running lengthwise of the roots. Side roots arise from an inner layer, and they must break their way through the outer tissues to reach the soil. Roots differ further from stems in that they do not have definite nodes or joints and they never give rise directly to leaves, flowers, or fruits. "Adventitious" buds sometimes form on roots, however, and these may grow out into shoots that in turn may flower and produce fruit.

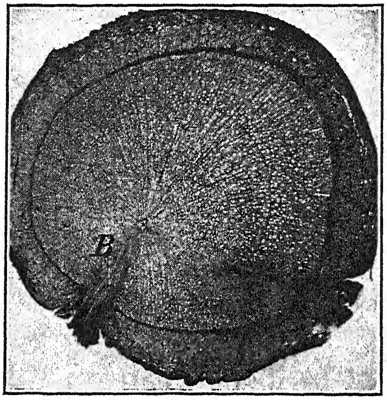


Fig. 4.—Cross-section of apple root, 2 years old. As compared with twig growth, simpler structure. Pith small, no distinction between primary and secondary wood. Emergence of branch root shown at *B*.

THE STEM

The primary function of the stems of fruit plants is to support the leaves, flowers, and fruit. It might almost be said that the stem, with its branches, is primarily a framework for holding the leaves up to the light. The second function is to act as connecting link between roots and leaves. In this capacity it serves not only to carry to the leaves materials absorbed by the roots, but also to transport elaborated food materials manufactured in the leaves down to the roots. Stems also afford considerable space for the temporary storage of food materials until they are required elsewhere in the plant for new growth or for flower or fruit formation.

Its Anatomy.—The trunk of a mature fruit tree is composed of a central mass of dead and physiologically inert tissues, surrounded by a relatively narrow zone of living and functioning tissues, which in turn is surrounded by an inert protective layer. The zone of functioning tissue includes the outer portion of the wood roughly equivalent to the "sapwood" of general

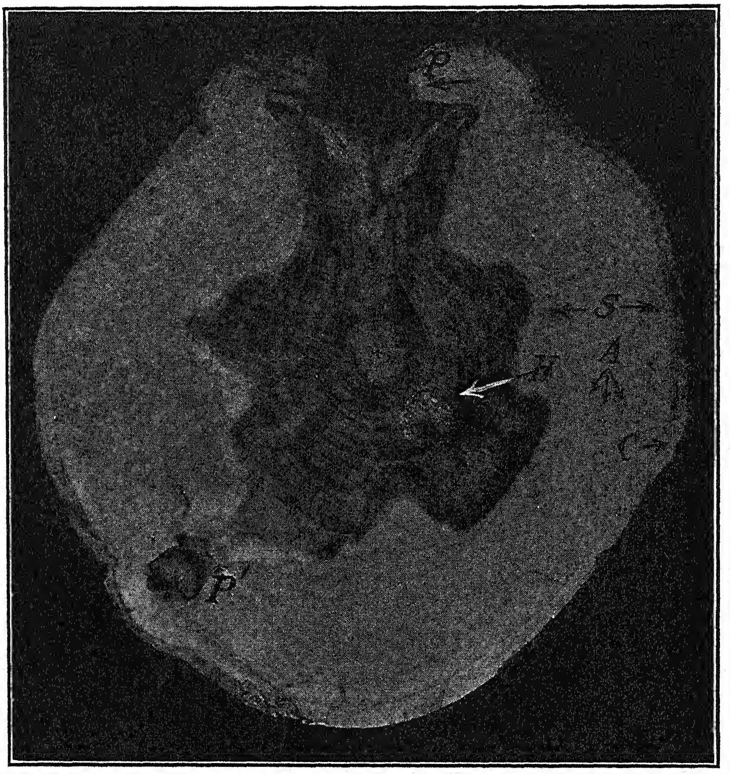


FIG. 5.—Cross-section of main scaffold limb. Heartwood *H*; sapwood *S*; annual rings *A*; cortex *C*; pruning wounds at *P* and *P'*; *P'* has completely healed over, while at *P* the process is not complete and rot has set in.

phraseology and the inner portion of what is commonly called the "bark" and between these a very thin layer called the "cambium," which provides for growth in circumference (Fig. 5).

The cambium is a tissue with which the orchardist has many points of practical contact. Its thickness is measurable only with the microscope and in viewing a cross-section the unaided eye sees its location rather than the tissue itself. During por-

tions of the year, the bark may be separated easily from the wood; when this is done the cambium layer apparently splits, part adhering to the bark and part to the wood. The jelly-like material which can be scraped from the exposed surfaces is composed, in part, of this tissue.

As seen through the microscope, cambium is a band of a few cells' thickness—in the apple six to eight. Some investigators hold that the true cambium is only one cell wide; in any case it is exceedingly narrow. The cells are flattened tangentially (at right angles to a radius from the center of the trunk); they are rich in protoplasm and have thin non-woody walls. Except for the flattened condition and regular arrangement, their appearance suggests that of the tissue of the growing point at the tip of root or stem. In fact, it is essentially the same tissue modified in form and arrangement by the pressure which it exerts against the solid wood on the inside and the relatively inelastic bark on the outside. The woody portion of the tree, above and below ground, is wholly surrounded by this tissue, continuous from the tip of the branch to the tip of the root.

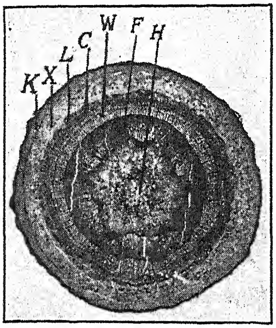


FIG. 6.—Cross-section of 3-year-old apple spur. Structure less simple than root. Pith *H*; primary wood *F*; *W*, secondary wood; *C*, cambium; *L*, phloem; *X*, cortex; *K*, cork.

Actual growth proceeds in this way: the cambium cells are constantly dividing, splitting off new cells toward the inside and toward the outside of the stem. Those originating on the inside become transformed to conductive vessels or woody supporting fibers or wood parenchyma cells, as the case may be; those given off to the outside constitute the phloem. These cells become modified in various ways, but they do not divide again; with relatively unimportant exceptions, new cells are formed only by the cambium. The cells composing the cambium layer become active in early spring; in the pear they have already formed new wood when the blossoms open. They apparently remain active, potentially at least, until the end of summer or into the autumn since "second growth" may begin certainly as late as August, and callus formation, a product of cambial activity, has been observed in apple trees wounded in mid-October.

Wood formed in the spring contains a number of large vessels; that formed later in the season is more dense. This alternation of porous and dense layers gives the wood, as seen in cross-section, the appearance of being composed of concentric rings. This is indeed the case. Ordinarily each ring in a cross-section marks a year's growth and the age of a trunk or branch at the point where a cut is made may be determined by counting the number of

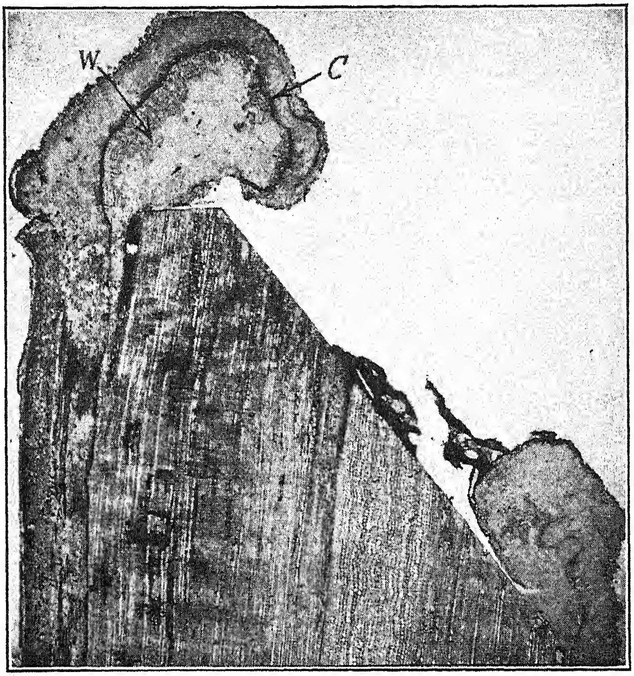


Fig. 7.—Longitudinal section of apple twig, showing callus formation below ground. Growth chiefly from cambial region; no typical cork cells as yet formed. In callus at lower right cambium formation incomplete, very few characteristic wood cells have appeared; at upper left, more advanced stage, with cambium layer *c* better developed and wood cells *w* rather numerous

these annual rings. The trunk is composed of a series of elongated cones, a new cone being superimposed each year on that formed in the previous year.

Repair (Regenerative Processes).—The cambium, in addition to providing normal growth, is concerned with repair of injured tissues. In several ways this is important to the fruit grower.

When the compression exerted by the bark on the cambium is removed, as when the bark is cut, the cambial tissue and its derivatives expand into the freed area; they lose much of the orderly arrangement that characterizes their development under pressure, and form a soft, irregular tissue known as callus (Fig. 7). This is familiar to fruit growers as the tissue which develops on the edges of a wound on a tree trunk or branch, the callus edges

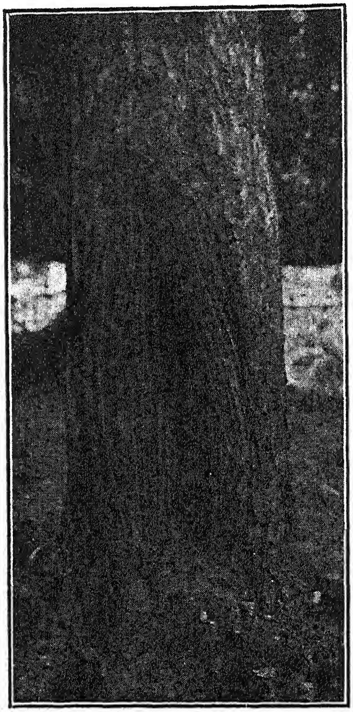


FIG. 8.—Closing in a wound by callus formation has been hastened in this case by slitting the callus.

advancing from the various sides until they meet, unite, and seal the wound. Above ground, callus rapidly forms bark which restores compression and the formation of the various tissues resumes its normal course (Fig. 7). Development of callus, and consequently the healing of wounds, proceeds more rapidly in vigorously growing trees; on large wounds it may be stimulated by cutting the edge of the callus, relieving the bark pressure again (Fig. 8). Though moist atmosphere favors callus formation,

other considerations make undesirable the bandaging of wounds as sometimes practiced; better results are secured by removing all dead bark, covering the exposed wood with a protective coating, and allowing the callus to develop as it will.

Pruning wounds or dead areas due to winter injury, fire, or sunscald can be covered with live tissue only through callus for-

Fig. 9.—Left: the "walling over" of a wound by callus formation at the edges; at the right, healing of a similar wound by cork regeneration from the exposed cambium and wood surface has taken place.

mation from the edges of the wound. In some wounds, however, live, rather than dead, tissue is exposed; these cases occur when the bark is torn loose by cultivator or by whiffletree or by sheep. Wounds of this kind are likely to heal by regeneration directly on the exposed wood (Fig. 9); this apparently comes from cambium formed from the very young wood cells or possibly from the cambium remaining when the bark was torn loose. Attempts to protect this area from drying out are likely to lead to destruc-

tion of the exposed tissues by mold; protective coatings are equally or more likely to destroy this tissue. The best treatment for wounds of this sort is to let them entirely alone, at least until it is certain that they are not going to regenerate new bark.

In hardwood cuttings, such as those by which new plants of grapes and currants are produced, callus seals the cut ends and presumably prevents invasion by destructive organisms. This callus is formed in a close, moist atmosphere and in appearance and in actual nature it differs from callus formed above ground, particularly in the absence of bark. In some plants the pith and

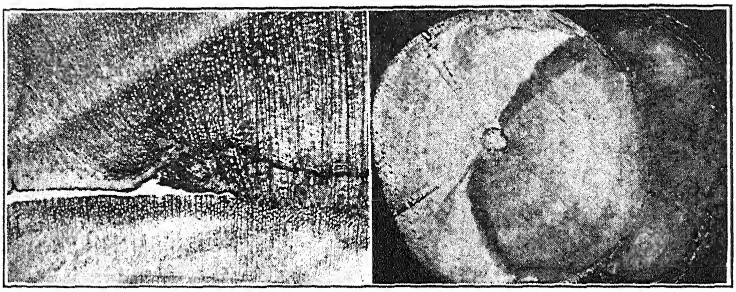


Fig. 10.—*Left.* Photomicrograph of section from the pear shown at right. On the right, regeneration tissue; on the left, walling over. Regeneration tissue is fastened rigidly to the older wood, while walling-over tissue does not unite with it.

Right. Cross-section of pear trunk girdled in midsummer, all the bark being removed. Regeneration followed on one side, forming new wood. This in turn sent out growths on the sides, beginning the walling over of the remainder of the trunk. More than half the trunk is dead and water apparently travels only in the portion near the regenerated wood.

the wood cells adjacent to the cut surface appear to form some callus, but the greater portion comes from the cambium.

Budding and grafting depend on cambial activity. If a bud with a piece of the bark surrounding it is cut properly from a twig and inserted properly under the bark of another tree of the same species, growth from the cambium and parenchymatous cells on the inside of the bark surrounding the bud unite with similar tissues from the surface of the wood of the stock; the bud remains alive and will grow in its new position. Success in grafting depends primarily on inserting the cion into the stock in such a manner that the cambial layers are approximately in contact; if this is done the callus growing from the one meets the

callus produced by the other and their interlocking accomplishes the union.

Structure of the Wood.—The woody cylinder of the trunk is composed of cells of several types. Running radially, *i.e.*, toward the circumference, are medullary rays containing box-like, non-fibrous (parenchymatous) cells (Fig. 6). These rays are prolonged beyond the cambium; they furnish channels for the movement of sugars and other foods to and from the interior and serve as a storage tissue for these materials and outside the cambium they store nitrogenous materials. They have, however, little direct connection functionally with the longitudinal tissues of the woody cylinder, in the midst of which they are located.

The wood fibers, which serve for mechanical support, are long, narrow cells, tapering at the ends, generally lignified and comparatively thick walled (Fig. 11); in the apple and other heavy-wooded plants they are very abundant. Their tapering ends permit overlapping, adding materially to the tensile strength of the tissue; this effect is enhanced by the irregular spacing of the fibers, making all points of uniform strength. When a branch bends, tensile strength becomes important in the tissues on the convex side of the arc. The mechanically weak point in trees is the lack of tieing together laterally of the fibers. This is illustrated occasionally by the tearing of a branch loaded with fruit on one side only, but more often by the splitting of narrow-angled crotches where the continued laying down of new wood on the inner angle acts as a wedge. At these points the fibers on the inner angle do not bend around the turn, but the fibers from the trunk and those from the upper edge of the branch run in a generally parallel course. They cross to some extent, thus in a measure providing some anchorage, but the main strength of the crotch lies in the fibers on the outer (or under) side of the branch.

The vessels, which constitute the main conductive tissue, have relatively thin walls and large cavities; their diameter is much greater than that of the other cells (Fig. 11). Large terminal perforations permit free movement of sap in its upward course, since these cells are arranged end to end in a continuous line, like tile in a drain.

The fourth major tissue of the wood is composed of wood parenchyma cells (Fig. 11); these are scattered about among the other cells and they store elaborated foods.

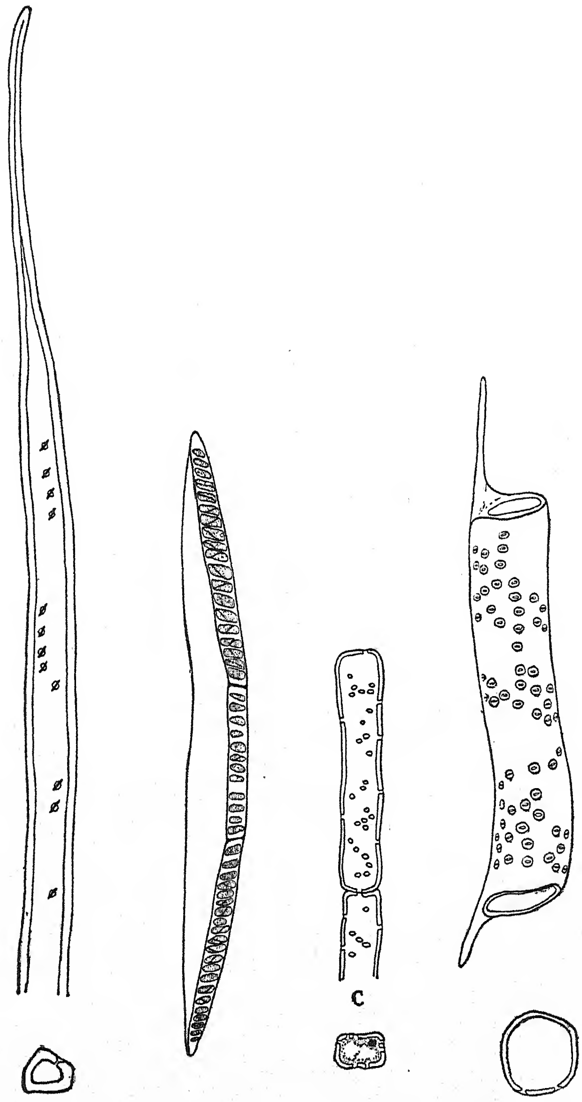


FIG. 11.—Typical cells of wood and phloem in apple, *A*, wood fiber; *B*, vessel; *C*, wood parenchyma; *D*, sieve tube. (*All from Eames and MacDaniels.*)

In addition to the openings at the ends of the vessels, all the cells in the wood have openings, called pits, along the sides (Figs. 2 and 11). These pits permit the passage of water from the upper end of one cell to the lower end of another that overlaps it; through these the water ascends and passes out at the upper end into the lower end of another cell. The pits permit lateral movement of water, either into the medullary rays and thence out to the phloem, or around the stem to the side which is most exposed to water loss or around a deep wound. Ordinarily conduction is most active through the wood most recently formed, *i.e.*, the outer layers, but if these are cut the water moves inward through the pits to older wood; through this it rises above the cut and then by the pits proceeds outward again toward the newer wood. The whole water-conducting system is characterized by a high degree of facility of adjustment, so that water can be, as it were, diverted readily to meet the needs of the moment.

As cells become older their conductive activity diminishes, accumulations of inorganic and organic materials begin, and the color darkens. The sapwood is becoming heartwood. There is no definite age at which this change begins—indeed it may commence at one side of an annual ring while the other is still functioning, and the sapwood remains alive longer in vigorous than in weak trees. Heartwood is inert physiologically—generally it is dead—but of great value as a support. This is shown by the vigorous growth in hollow-hearted trees in which the heartwood has decayed, though they are likely to break in a high wind.

The Bark.—The region outside of the cambium is loosely called bark. Next the cambium is the phloem; this contains, along with fibres and parenchyma cells, the sieve tubes through which elaborated foods descend. These receive their name from the numerous perforations in the ends of the cells; through these the food materials pass to the abutting cells. In the apple the ends are oblique, thus increasing the surface through which the materials may pass (Fig. 11). Some of the carbohydrate is diverted to the medullary rays, through which it travels into the woody cylinder for storage in the parenchyma or in the rays themselves, but much of it travels down in the phloem to the roots. Outside the phloem region is the cortex, composed of cells approximately spherical in shape and without lignified walls (Fig. 6); their chief function is the storage of food. This tissue, however,

is more pronounced in young twigs; in mature trunks of many species it is cut off, along with the outer portion of the phloem, by the successive formation of layers of cells of cambial nature called the "cork cambium." In the apple and pear this latter tissue arises near the surface and leads to the first scaling off of the outer layers of cork; as the smooth bark changes to rough, areas affected this way are sometimes erroneously considered diseased. This layer, in old stems, is considerably closer to the wood than it is to the surface of the bark. Sometimes a cleavage occurs along a cork cambium layer and in bridge and approach grafting the unwary operator may be deceived into thinking the true cambium is exposed and set the grafts accordingly. These grafts do not succeed. Cork cambium may be distinguished with the unaided eye from the true cambium by its lack of the glistening surface the latter presents and by the softness of the underlying tissue. The formation of the cork cambium excludes the outlying tissues from food and moisture supply; they then become corky and function chiefly as protection against water loss and to some extent against mechanical injury and temperature changes. When the bark reaches the stage where the cork layers peel off—the "rough bark" stage—sunscald is far less likely to occur. Cork cambium may be formed by the parenchymatous tissues near a wound; this forms cork and in this way seals the wound.

The practice, rather common among farmers, when they wish to kill trees and prevent sprouting from the roots, of girdling them (removing a ring of bark around the trunk) in midsummer to "prevent the sap from going down to the roots," though based on a conception not precisely in accord with scientific definition, is fundamentally correct. In general, though not with entire correctness, it may be said that sap ascends and only elaborated foods descend. The ascending watery sap carries nutrient salts in solution; in the leaves the water is transpired to the air and some is consumed otherwise and the descending movement is of material which hardly fits the ordinary conception of sap. The upward movement is chiefly in the sapwood; the return, or downward, movement is in the phloem, a region popularly known as the "inner bark."

Length Growth.—As long as a tree lives, it grows in length as well as in circumference. Length growth is made only at the tips of the shoots, though of course the term includes the growth

of side branches. Here each shoot has, enclosed in a bud during the winter and in a rosette of very young leaves during the period of actual growth, a small mass of specialized tissue called the growing point. This is the true tip of the branch. The cells composing this tissue are very densely crowded; they are full of protoplasm and have very thin walls. A few of these cells divide very rapidly, giving rise to new cells, which form a dome whose apex is the growing point. Pressure from within expands this dome outward, so that the newly formed cells quickly come to a position parallel to the axis of the shoot while the growing point is simultaneously raised. These processes are continuous during periods of growth. For a time after they have come into position the newly formed cells continue to enlarge and in this way produce length increase in the region just below the growing point. This growth may be inferred from observation of the shortness of the distance between the points of attachment of the young leaves on the shoot as compared with the distance between the attachments of the fully formed leaves. Away from the tip, however, length growth does not occur; if each of two buds, 6 inches apart, sends out a branch and the branches survive, their centers will be 6 inches apart 50 years or two centuries afterward.

In some species and varieties the strongest, most vigorous shoots are produced from terminal and subterminal buds. The result is a more or less upright, tree-like type of growth. In other species and varieties the strongest shoots are produced from the more basal buds. This results in a bushy or shrubby type of growth.

Buds.—Fundamentally, a bud is a growing point, of undifferentiated tissue, surrounded by embryonic leaves or blossoms; these in turn are protected against desiccation and mechanical injury by an envelope composed of numerous scales (Fig. 12). Buds are variously classified, according to the purpose in view when the classification is made. Fruit growers often speak of "fruit buds" (containing blossom buds) and "leaf buds" (not containing blossoms). In discussing pruning they may refer also to terminal buds and lateral buds, separating them according to position and a bud may be described by two standards at once, *e.g.*, "lateral fruit bud." Other classifications are used as occasion arises.

When growth begins the bud ceases to exist as such; when growth stops for the winter a new bud generally forms. Pro-

longation of growth late into the autumn may prevent the formation of terminal buds; this sometimes happens in apples where the growing tips are in an "arrested" condition. A bud which does not open in the spring, but remains alive and possesses the potentiality of subsequent development, is called a "latent" bud, in contrast to dormant buds, which are merely awaiting proper seasonal conditions for development. Terminal buds are dormant during the winter, but only in rare cases are they latent.

In most species only a single bud develops in the axil of each leaf, but in certain others, *e.g.*, the walnut and pecan, two, three or even four, may develop. In some varieties of Japanese plum as many as a dozen may develop at a single node. Occasionally

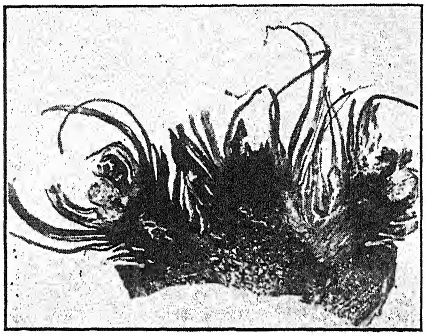


FIG. 12.—In center, terminal (leaf) bud of sour cherry. At sides, lateral blossom ("fruit") buds.

buds appear at other points, being neither terminal on stems nor lateral in the axils of leaves. These buds are called adventive or adventitious. In some instances, as already mentioned, they may appear on the roots; more often they develop on the stem or on its branches and occasionally they may develop on leaves.

Buds formed in the regular way may remain latent for a number of years; they may even become buried under a considerable layer of bark and finally push out into growth, generally as "water sprouts." Careful examination of the branch at the point of origin of these buds demonstrates the uninterrupted connection between the pith of the original branch and the pith of the latent bud, maintained perhaps across ten or fifteen annual rings. In this respect they differ from the adventitious buds, which arise irregularly in the bark and have not even the slight connection with the interior of the stem that is maintained by the

latent buds. The formation of the latent buds occurs when the shoot is young; adventitious buds are formed later. Shoots arising from either latent or adventitious buds are for a time but feebly attached to the parent branch and they are torn out easily at any time until their bases have become anchored in the stem by the deposition of several successive annual rings of wood. Sprouts arising from roots originate wholly as adventitious buds. These form more freely in some species than in others; in some cases (blackberries and some plums) they are used in multiplying plants, while in others (Morello cherry) they become nuisances in the orchard.

THE LEAF

The leaf is the food-producing organ, the real workshop of the plant. For its manufacturing processes it requires, in addition

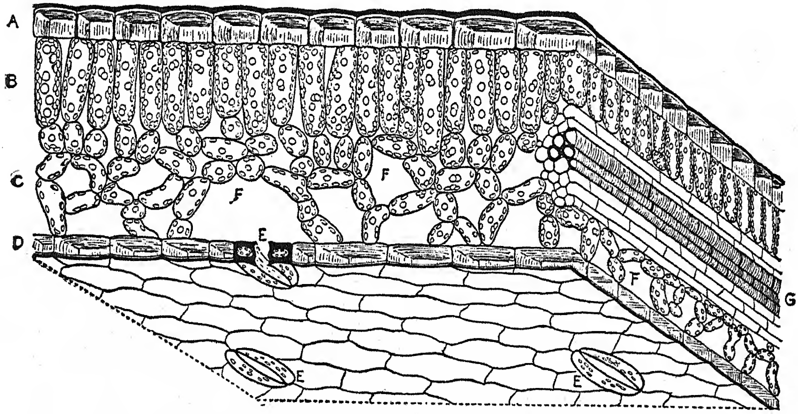


FIG. 13.—A small fragment of a leaf blade, seen in three planes and highly magnified. *A*, upper epidermis, covered by cuticle (in black); *B*, palisade layers; *C*, spongy layer; *D*, lower epidermis, covered by cuticle; *E*, stoma (in one case seen in section); *F*, air space; *G*, vein, cut lengthwise. (*After Sinnott.*)

to water and mineral nutrients obtained through the roots, considerable sunlight and carbon dioxide which it obtains from the air. Since the acquisition and utilization of both of these are essentially surface phenomena, leaves must expose as large an area as possible to light and air, and most leaves are composed of flat blades held out to the light by a stalk or petiole. Near the base of each petiole is a pair of small structures, the stipules; these vary in prominence and degrees of persistence. The veins of the leaf mark the location of the vascular bundles or strands

which branch off from the bundles in the stem and run out through the petiole and midrib, there to branch and subdivide again so that every part of the leaf may be supplied with water and nutrients from the soil and so that manufactured food products may be carried back to stem, fruit, and roots for storage or utilization, as the case may be.

On the top and bottom of a cross-section, as viewed under the microscope, are single layers of colorless epidermal cells (Fig. 13). Here and there these layers are punctured by minute openings called stomata. In the leaves of many species, as the apple, stomata are found only on the lower surface. Closer examination shows that each stoma is an opening between two specialized cells called guard cells, which can alter their shape under the influence of light in such a way as to enlarge the opening between them or close it completely (Fig. 14). These stomata, regulated by their guard cells, are gates through which the plant receives some of the raw materials required in its workshop and through which it discharges water vapor and the major portion of the other by-products of its manufacturing activities.

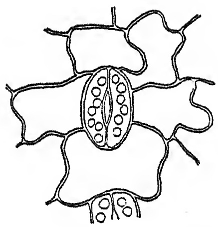


FIG. 14.—Stoma of apple leaf. (*After Eames and MacDaniels.*)

Between the upper and lower epidermal layers, the leaf is filled with green cells. Those of the upper half are elongated and arranged in neat rows close together, a characteristic giving rise to the name "palisade cells." These cells are packed with chloroplasts, the plastids containing the green coloring matter, and they do the work of food manufacture. The lower half of the leaf is filled with irregular, pale green cells loosely arranged in a spongy mass with large air spaces between them. The air spaces are connected through the stomata with the outside air.

THE PLANT AS A WHOLE

Structurally the fruit plant may be regarded as consisting of two comparatively simple groups of thin-walled actively working cells: below ground the root tips and root hairs, whose function it is to obtain the water and nutrient supply, and above ground the palisade and other mesophyll cells of the leaf whose chief function it is to utilize these materials, along with carbon dioxide, in the manufacture of more or less complex organic food materials.

Connecting these two active, vital portions of the plant is the stem and its branches with their more complicated structures and also the conducting portion of the roots below and of the leaves above ground. These intermediate structures serve also as storage organs, as anchors for the plant as a whole, as a framework for the attachment of absorbing roots and manufacturing leaves, and in still other capacities; but their main function is that of a trunk and branch-line transport system between the two principal working units in soil and air. To man, fruit production is of primary importance; to the tree it is only one of several functions; man's endeavor to secure and maintain fruitfulness in trees must be founded on the well-being of the tree itself.

CHAPTER II

TREE GROWTH

Plant growth is one of the most familiar of all phenomena. The common saying, "Tall oaks from little acorns grow," appeared first in a schoolboy theme. Trees grow taller and spread further year by year; half-grown fruit increases in size and changes in color as the season advances; the shoot of vine or bush lengthens almost overnight. The period when these things are going on is known as the growing season and a shorter period in the spring and early summer is recognized as a time when growth is especially rapid. This period of rapid growth is followed by a period of decreasing growth, a progressive slowing down of activities until finally a stage is reached when apparently growth stops. This seemingly quiescent state may be reached only on the advent of cold weather or of drouth, or it may come on apparently independent of outer changes. In any case successive periods of growth and quiescence alternate with each other; that is, with most fruit plants growth is periodic rather than continuous.

THE RESTING PERIOD

There are periods when some kinds of fruit trees not only fail to grow, but actually cannot grow, even though environmental conditions are favorable. Most deciduous fruits enter this period in late summer or early fall and come out of it gradually during winter or early spring. The resting period thus corresponds in part to the dormant period enforced by low temperature in cold sections and by drouth in some arid regions. Usually it begins some time before the advent of the dormant season and it ends some time before the return of growing conditions in the spring. Trees do not necessarily keep on growing throughout the growing season and they do not necessarily start to grow with the first warm days of spring. In both cases the response is to internal conditions rather than to external circumstances. In the most southerly states apple and peach trees remain dormant during

winter months which are as warm or warmer than the spring weather in which their buds open in the northern states. In the south the resting stage outlasts the dormant season, in the north, cold weather is prolonged beyond the end of the rest period.

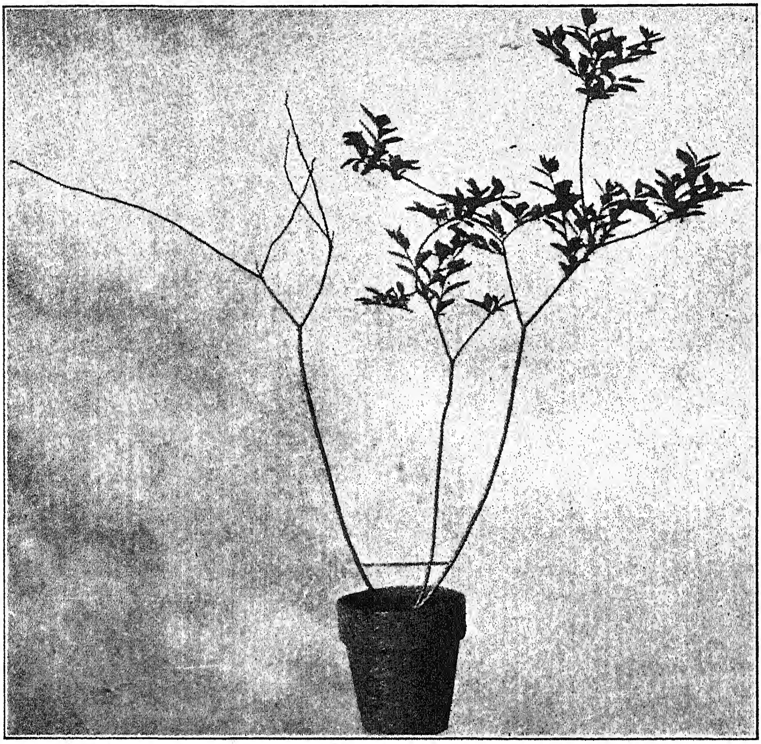


FIG. 15.—A blueberry plant; in the branch at the right the rest period was broken by exposure to cold; that at the left is still in its resting period. For several weeks preceding the taking of the picture the entire plant had been exposed to growing season temperatures. (*After Coville.*)

IMPERCEPTIBLE GROWTH PROCESSES

What has been said does not signify that all growth is visible. At the beginning of the growing season and again toward its close, growth is slow, sometimes almost imperceptible. Furthermore, during at least a part of the time when the plant is apparently quiescent, important growth processes may be in progress. In reality growth begins with the differentiation or laying down inside the seed or bud of many of the parts found in trees or vines

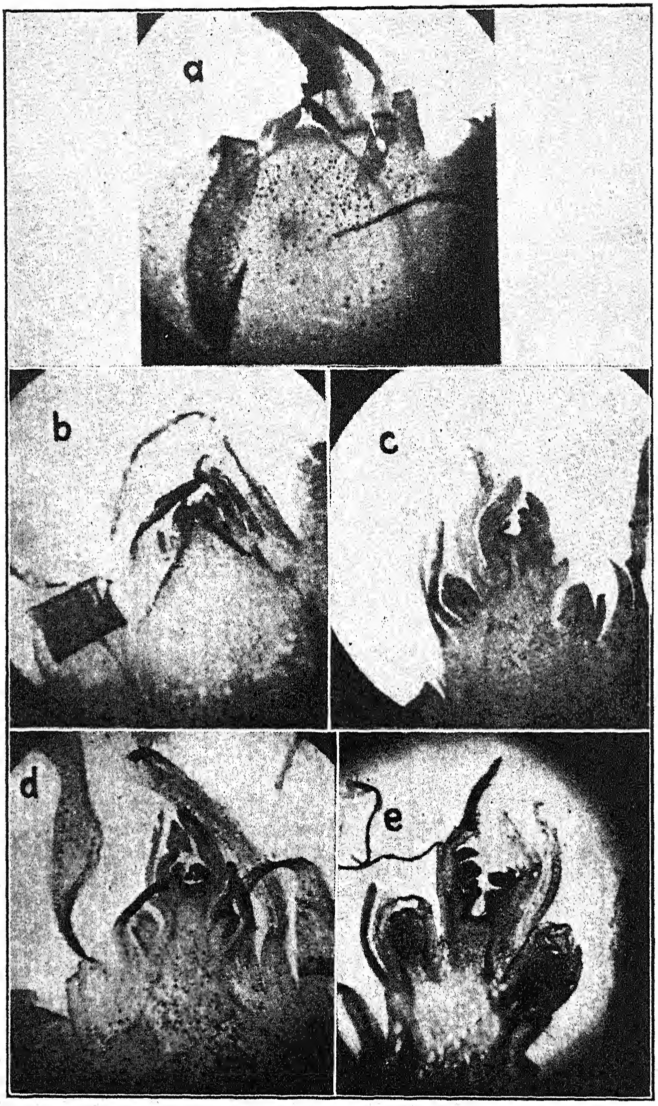


FIG. 16.—Successive stages in the development of an apple fruit bud: (*a*) June 24, no differentiation of flower cluster parts evident; (*b*) July 21, the elevated crown or growing point indicates flower bud differentiation; (*c*) Aug. 5, three embryonic flowers clearly visible in longitudinal section; (*d*) and (*e*) more advanced stages, Sept. 10 and Feb. 14.

that are in full flower and leaf. Examination with a hand lens or with a microscope reveals their presence in miniature. For example, in many species the formation of the blossoms that open in spring begins early the preceding summer and their development proceeds throughout summer and fall (Fig. 16). These are as truly growth processes as the elongation of shoots in summer, though they are not conspicuous. The only visible indication may be a slight swelling of the bud. These growth processes are fully as important to the fruit grower and to the life and perpetuation of the plant itself as those that are more readily discernible.

Changes of a different nature go on after increase in size and new tissue formation have practically ceased, and this too is growth, at least in the broader sense of the term. An apple or strawberry or grape grows larger and larger until it attains full size, but it is still green and hard, unfit for eating. In another week or month it is soft, red, and palatable. Internal changes have occurred, perhaps largely of a chemical nature, unaccompanied perhaps by change in size or shape. The fruit has ripened. In a comparable way a twig or shoot may show no increase in length or diameter during the last few weeks before frost but it may be undergoing internal changes that prepare it for the cold of winter. It is acquiring maturity. Growth in the sense of new tissue formation has not taken place, but there has been rapid development in hardening or lignification within the tissues already formed. To hasten or retard these internal growth processes is as much and as frequently the object of cultural practices, as to promote that type of growth that may be measured in inches.

NEW TISSUE FORMATION

Increase in the size of the plant or of its individual parts, such as leaf or fruit, is the result of new tissue formation. This is a process of making more material like that of the plant that is growing—more fruit or root or bark. In a sense the making of plant tissue is much the same as the manufacturing of any other product, as, for example, the making of waffles. These can be made from the following ingredients: 1¾ cups of flour, 3 teaspoons of baking powder, ½ teaspoon salt, 1 cup of milk, 2 eggs, 1 tablespoon melted butter. This recipe will make about four cups of batter. If we decide to have waffles for breakfast, we

proceed to collect all the necessary ingredients. We may find plenty of flour, baking powder, salt, eggs, and butter, but only ½ cup of milk. The only solution is to halve the recipe, make two cups of batter, and tighten our belts. We may have 5 pounds of salt, but that does not help the situation. Some morning we find that the supply of baking powder is exhausted. We need only 3 teaspoonsful. We might try to omit the baking powder, but then we should not have waffles. One teaspoonful would give us 1⅓ cups of batter, but lacking that we must be discontented with something else, until we can get more baking powder. When the supply of any one of these ingredients gets low it must be replenished or there will be no waffles.

Fruit trees and the products they bear are made in the same general way from a number of ingredients. Some idea of just what these plant ingredients are may be obtained by sending a small tree or vine or their fruits to an analytical chemist and securing a statement of the kinds and amounts of different elements and compounds that he finds. The report of such an analysis would probably bear a close resemblance to a catalogue of the chemical elements, as almost every known element has been found in one plant or another. It would hardly seem probable that all of these elements are necessary. As a matter of fact, they are not. Some are to be regarded rather as impurities, comparable to a bit of sand or grit that might occasionally find its way into a waffle. Their presence is more or less accidental and in no way essential to growth. The only way to find out definitely whether a particular element is essential, is to try to grow the plant without it. If the plant grows in a perfectly healthy manner, the element in question is obviously not necessary for plant growth. To carry out an experiment of this sort, the plant must be grown in a medium of known composition. Many plants have been grown in water to which pure salts have been added in various combinations, and extensive experiments with water cultures of this sort have shown exactly which mineral salts are essential for growth and which of them can be omitted.

Experiments of this sort with a wide variety of plants have shown that all green plants require the same mineral elements. It is interesting that all the elements essential for plants are likewise essential in the human diet, though man requires a few elements that apparently are unnecessary for plant growth.

In addition to the water and salts that plants take in through their roots, carbon dioxide is essential for the growth of green plants. This is absorbed from the air through the surfaces of their leaves and is used to combine with water to form carbohydrates, such as sugar and starch. In due turn a certain percentage of the carbohydrates is used either alone or in combination with mineral elements for transformation into other groups of compounds such as oils, acids, and proteins. Finally compounds of these various groups, together with water and salts, are used in the making of new tissue, *i.e.*, in growth.

The following recipe gives very roughly the constituents that an apple tree uses for increasing its weight by about 300 pounds:

25 gallons water	95 pounds carbohydrate
5 pounds nitric acid	1 pound lime
4½ ounces phosphorus	1 pound potash
2 ounces sulphur	5 ounces magnesia

50 grains iron

The grower cannot produce an apple tree, however, by mixing together the ingredients given in this recipe, for the tree is its own cook and no strangers are allowed in the kitchen. Only an apple tree or an apple seed can make new apple tissues. All the grower can do is to assume the role of a considerate grocer and see that the tree is always adequately supplied with the necessary ingredients. An apple tree cannot use a surplus of phosphoric acid to make up a deficiency of sulphuric acid any more than the cook can substitute salt for baking powder in making waffles. If some apple trees have only 1 pound of nitric acid at their disposal they can make only 60 pounds of new tissue, instead of the 300 pounds they might make if 5 pounds were available. This means that the new growth of shoots, roots, and wood, of leaves and fruit would be only one-fifth of what could otherwise be made. In brief, the amount of growth is limited by the deficient ingredient regardless of whether this substance is required in large or in small amounts. No more growth can be made with 25 grains of iron than with 2½ pounds of nitric acid.

COMMON DEFICIENCIES

The apple tree in the average soil is like the family living in the country. Most of its nutrient and food constituents are always

at its disposal, though certain of them are every now and then running out. Only two or three constituents need cause the grower any particular concern, as these alone are the substances he may be called upon to supply. Except in rare instances, the fruit tree can obtain plenty of lime, potash, magnesia, iron, phosphoric and sulphuric acid. There are few orchard soils that do not contain plenty of these compounds where fruit plants can get them. Scarcity of the three other constituents—water, nitric acid, and carbohydrate—causes trouble with greater or less frequency, and the orchardist should know how to recognize the first symptoms of their deficiency and when and how best to replenish the supply.

The water actually required for growth is much greater than that indicated in the recipe. The amount shown there is only what might be recovered from 300 pounds of new tissue. An amount many times larger is required to compensate for enormous losses in the form of water vapor from the leaves and because of these losses water is the important factor it is in the growing of plants. Whether or not much effort must be expended to ensure adequate provision for water depends on the size and kind of plant grown, on the soil and on the amount and seasonal distribution of the rainfall. In commercial fruit production, moisture supply in one way or another, directly or indirectly, limits growth, longevity, yields, quality, and grade of product and affects profits as frequently as any other environmental factor. At least a third of what is called cultural practice is for the purpose of controlling or modifying this growth factor or of adjusting the plant to it.

The nitrates are not the only compounds of nitrogen that can be used for plant growth. Ammonia or nitrous acid may be substituted in part or in full for it. The important point is that the plant obtains a certain amount of nitrogen in one of these forms. Under ordinary orchard conditions, when the supply of water is adequate, the plant is more directly and immediately responsive to nitrogen than to any other nutrient element. This applies particularly to top growth, the lengthening of shoots, and the increase in size of all parts of the plant above ground. The entire supply of nitrogen for top growth must pass through the roots and the shoots presumably receive only the difference between what the roots absorb and what they use for their own growth.

This situation is almost exactly reversed for carbohydrate. Since it is manufactured in the leaves, the adjacent shoots are well supplied and their growth is seldom hampered by a lack of it. The rest of the plant likewise depends entirely on the leaves for its supply. This dependence is greatest in the roots, which appear to receive only what is left over from top growth and, in consequence, carbohydrate supply is often an important limiting factor in root development. Root starvation because of a limited carbohydrate supply is most likely to become acute and to result in the death of the roots after girdling or partial girdling of trunk or crown from winter killing or insect, disease, or rodent attack. This effect follows because the carbohydrates pass from top to roots through the inner layer of the bark and not through the wood. Injury to roots from lack of carbohydrates will, in turn, lead to injury to a part or the whole of the top from a deficiency in nitrates or in water.

Fig. 17.—Young and old bridge grafts spanning a girdled area on the trunk of an apple tree.

There is no practicable direct way of supplying trees or any of their parts with carbohydrates, as there is in the case of nitrates and water. However, much can often be done to improve the conditions favorable for carbohydrate manufacture or to prevent a wasteful consumption of carbohydrate material that the plant ordinarily makes. Protecting the foliage from attacks by injurious insects and fungi or from spray burn is perhaps the most important means of modifying carbohydrate manufacture; the best means of regulating carbohydrate utilization and storage is by controlling the available nitrogen supply; bridge grafting (Fig. 17) is the principal means of mending a break in the system which conducts carbohydrates from top to root.

CONTROLLING GROWTH THROUGH BALANCING NUTRIENT SUPPLY

To determine in exactly what proportion the various nutrient and food materials are used, or in exactly what combination they must be present for shoot or root growth, for fruit development, or for fruit-bud formation is still a problem. There is good reason to believe, however, that when certain ingredients are present or available in certain proportions or concentrations, growth is promoted; if other proportions or concentrations exist, growth is checked; furthermore, if growth is promoted it takes certain fairly definite directions determined by the kinds and proportions of food and nutrient materials present. For example, a relatively high proportion of nitrogen to carbohydrates tends to promote vegetative growth; the inverse proportion appears to promote storage of organic food substances and, in the case of ripening fruits or foliage of certain kinds, it leads to the formation of the pigments which produce the various colors. Much recent effort of investigators has been expended to determine more or less exactly the internal nutritive conditions associated with the various ways in which the tree grows. Study of the way in which various pruning, cultural, and fertilizer treatments influence growth will show how to recognize the nutritive condition the tree is in and will suggest treatments it should receive.

TEMPERATURE IS A LIMITING FACTOR FOR ALL GROWTH PROCESSES

Temperature has been mentioned as a factor associated with periodicity of growth. This, however, is one of the least important of its influences. No feature of environment more profoundly influences growth processes or so completely and absolutely determines what the plant does, how it does it, and even where it can or cannot grow. At all times and in all places the plant is subject to the influence of temperature. If the temperature is low, growth is retarded; if it is still lower, growth may be suspended; in extreme cases the plant is killed. Up to a certain point, as temperature rises, growth processes are accelerated; when it goes still higher they are again retarded and very high temperatures kill the plant. Certain plants do best only within rather narrow temperature ranges and individual growth processes may likewise proceed best only within a definite temperature range, some being carried on best in one range and

others at a somewhat different range. Thus for the development of high quality in European grapes relatively high temperatures must prevail during the ripening season and the opposite is the case for the development of high quality in many apple varieties. Little can be done to change temperatures or the temperature requirements of plants or to change their response to different temperatures. Climate must be accepted about as it prevails and similarly the plant must be accepted with the characteristics it has inherited from its ancestors. There is a wide range and variety of plants, however, from which to choose. Fruit growing can be and has been adjusted to temperature—and likewise to some extent to soil and to natural moisture supply—by attempting to grow only those types, varieties, and strains that are found to do reasonably well under prevailing conditions.

CHAPTER III

THE TREE'S WATER REQUIREMENTS

The area comprising the United States contains types of natural vegetation varying from the deciduous forests of the eastern states to the deserts of Arizona and California, from the subtropical forests of Florida to the lake marshes of northern glaciated regions and the sparse grasslands of western Nebraska. Though these plant groupings are the product of several components of environment and though the distribution of any single species may be determined principally by temperature or by soil conditions or by historical circumstances, the general grouping into grassland or forest and the like corresponds more closely, perhaps, to rainfall distribution than to any other single factor. Acting with rainfall distribution is the evaporating power of the air, which varies tremendously in intensity between different sections. The rainfall measures the supply and the evaporation indicates something of the demand; the ratio between them may fluctuate even more strikingly than the rainfall. Evaporation determines why wheat farming prevails at one point while grazing on rather sparse grassland is the only agriculture feasible at another point with the same rainfall.

The supply of water often affects the soils themselves. In arid regions soluble salts accumulate in soils from lack of water to leach them out; these soils are likely to be fertile, though the accumulations may take the form of "alkali" and be detrimental. Soils in humid regions are leached by rainfall and the supply of soluble salts at any time is comparatively limited; on the other hand, the supply of humus, about which many important processes revolve, is likely to be greater and more lasting, and alkali is virtually unknown. Hardpan is, in part, a product of climate. Atmospheric moisture, likewise, has its effect on plant life. Besides regulating, more or less, the evaporating power of the air, it affects its permeability to light waves. The air of arid regions generally is low in water vapor, and atmospheric radiation is, therefore, less impeded than in humid regions and tem-

perature fluctuations between night and day are likely to be greater; night temperatures tend to be abnormally low in arid regions. Since water vapor absorbs certain of the light rays, sunlight is less intense in humid regions. This has, at times, a measurable effect on plants. Perhaps it is on account of these two factors that apples and pears from the arid regions generally have a finer finish and are more pleasing to the eye than those from humid regions.

Plants which are native to arid regions usually have special adjustments, structural or chemical, by which the loss of water is retarded and the small supply available is made to suffice. Most of the plants cultivated for fruit, however, were brought to America after a long sojourn in regions where lack of moisture is not often a critical matter—many of them, indeed, originated in these regions—and they do not possess special adaptability for conserving moisture. Their cultivation has spread into arid regions only because man's engineering skill has enabled him to supply water to certain areas in these regions. Man has not been able to extend the area of fruit culture by modifying temperatures but he has extended the area very materially by irrigation enterprises. Difficulties have been encountered here and there; alkali troubles, seepage, leachy soils, unsuitable temperatures, acreage in excess of the water supply—these and other difficulties—have eliminated some projects or some farms from the fruit-producing areas. Nevertheless, 45 per cent of the commercial apple crop of the United States, 35 per cent of the cherries, 40 per cent of the peaches, 65 per cent of the pears, 70 per cent of the plums and prunes, and 65 per cent of the oranges—60 per cent of the entire commercial fruit crop—is now produced on land that a generation or two ago was supporting a scant growth of sage brush, chapparal, and bunch grass. The industry that has developed in these areas that formerly were "waste places" has been made possible by water. Indeed the first commercial fruit growing of which there is record began with the aid of irrigation and when the irrigation systems were no longer maintained fruit growing disappeared from those areas (Fig. 18).

For many fruit growers the winter snowfall in the mountains, which governs the amount of water available for irrigation the next summer, is a matter of extreme importance and a rather large porportion of American fruit growers spend many summer

days diverting water from one flume or furrow to another to secure its proper distribution throughout the orchard. This task offers opportunity for some real nicety of judgment.

In humid regions, fruit growing is not without its moisture problems. Though the average rainfall may be ample, it is only an average composed of fluctuations above and below. Now and then a prolonged succession of months of scanty rainfall occasions serious damage to orchard crops and produces marked effects on young trees. The margin between scarcity and plenty is sometimes so slight that a day's rain at a critical time may

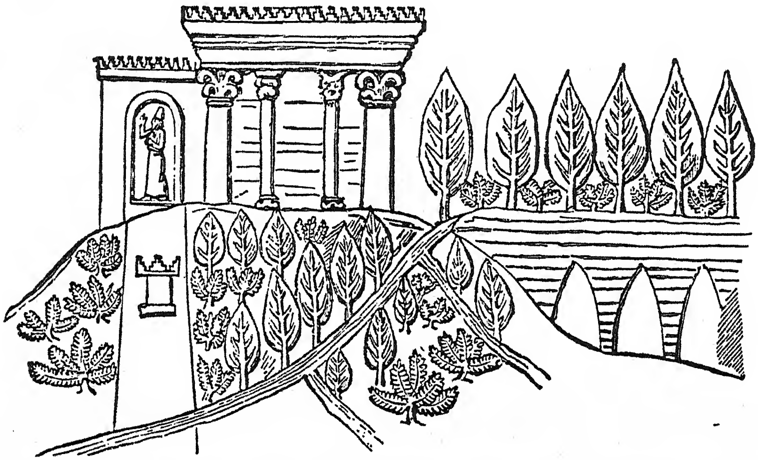


FIG. 18.—Irrigation in ancient Assyria, as depicted in the palace at Koyunjik. An aqueduct is shown at the right and laterals in the foreground. (*After Rawlinson*, 1870.)

ensure proper size in fruit; two or three weeks of drouth may so increase the percentage of undersized fruit as to reduce profits very materially. Furthermore, some fruit soils are so chronically dry, by reason of very high porosity, that only in unusually wet seasons are they naturally supplied with adequate moisture.

THE TREE'S WATER REQUIREMENTS

An ordinary fruit tree, such as the apple, consumes about 500 pounds of water for every 3 pounds of new dry matter produced, though this 3 pounds of new growth contains on the average only about 2 pounds of water. The major constituent

of the single pound of dry matter remaining is carbohydrate for the production of which about 6 ounces of water is required. It follows then that the apple tree retains about 2 pounds and 6 ounces out of every 500 pounds of water used—less than one-half of 1 per cent.

A more vivid conception of the significance of a water requirement of 500 pounds for every pound of dry matter that is produced is conveyed by a statement of the amount of water that would be used by a tree. An apple tree 30 years old may be assumed to produce at least 100 pounds of new wood, roots and leaves in the course of a year; this would be an increase of about 33 pounds in actual dry weight. A crop of 5 bushels would involve the production of another 36 pounds of dry matter. A tree producing about 70 pounds of dry matter in a season would require, at the rate of 500 pounds of water for each pound of dry matter, 35,000 pounds or 17½ tons of water a year. It would be evaporating water into the air at the rate of nearly ½ barrel a day as long as it was in leaf. Doubtless at times during the height of the growing season, transpiration losses per tree will exceed 1 barrel per day.

An acre of well-spaced apple trees, of this description, would take up 700 tons, or 175,000 gallons, of water in the course of a year. In other words, the equivalent of 7 inches of rainfall is actually absorbed and disposed of by the trees. This is on the assumption of a yield of 200 bushels to the acre. Every increase of 50 bushels per acre would increase the required rainfall 1 inch, so that at least 11 inches of rainfall would be required for the production of a 400-bushel crop, a 10-bushel per tree yield. This yield, incidentally, is well below the average for some of the best maintained orchards. The same idea can be worked backward. Every decrease of 1 inch in the rainfall would, theoretically at least, cut 50 bushels off the yield per acre or 60 pounds of apples from each tree.

When surface run-off, seepage, and evaporation are considered, 30 inches of rainfall seem barely enough for successful apple growing, though it is true that apple trees grow with less. When the natural supply consistently falls much short of this amount irrigation usually becomes necessary. Under average conditions at least two-thirds of the water that falls as rain escapes before the roots can absorb it and if the soil has low water-absorbing or water-retaining capacity, or if poor methods of orchard manage-

ment are used, the proportion of water that is lost to the tree may be much greater.

The figures that have been given are of course only approximate. There are many factors that together might increase or decrease the estimate by as much as 10 inches of rainfall. Each kind of plant has its own water requirement, some much lower than that given for apple trees and some considerably higher. Furthermore, the water requirement of a single kind of plant is by no means constant under all conditions, for plants have a rather remarkable power of adapting themselves to their environment. Atmospheric conditions such as wind and humidity, the texture and composition of the soil, the topography of the land, and many other circumstances would have to be taken into consideration before an accurate estimate could be made for any specific orchard. However, the figures that have been given strike a fair average and give some conception of the relatively great quantities of water required in fruit growing.

The apparently prodigal way in which plants use or waste water is not readily understood without realization that this loss or waste is incident, if not entirely prerequisite, to the acquisition of something else of equal or greater value. Carbohydrates are required for growth and are used extensively for the building of new tissue. They are made from water and carbon dioxide with the aid of light. For this process of manufacture, carbon dioxide is required in large quantities. Its mere presence in the air surrounding the leaf is not enough; it must actually enter the leaf and become dissolved in the cell sap before the green coloring matter of the cells can act on it chemically. The plant must expose a large surface to the air, and this surface must be of such a character that the carbon dioxide can permeate it readily. To provide such a surface is one of the functions of the leaves. The pores, or stomata, which admit carbon dioxide, permit water vapor to escape as readily as carbon dioxide enters. The plant virtually exchanges what its roots usually can get from the soil for what it must have from the air.

The orchard should be supplied not merely with enough water for vegetative growth and moderate crop production, but with enough to meet the maximum requirements of a heavy crop, for if a tree has a supply insufficient for both growth and ripening of a full crop, the available supply is generally used for vegetative growth first. Leaves actually take the water away from the

fruit in case of extreme drought; the fruit withers, the withered fruit drops, and the crop is reduced accordingly. Water which reaches the fruit is the surplus remaining after the requirements of vegetative growth are satisfied.

Of importance equal to the fact that trees require relatively large amounts of water is a consideration of the fact that the demand varies greatly from time to time and that the supply in the soil should always be ample to take care of the "peak load." At night trees transpire very little water possibly partly because

FIG. 19.—Furrow irrigation in a sweet cherry orchard in California.

their stomata are closed, certainly partly because atmospheric conditions are less conducive. During the day they are open and, in bright sunlight, low atmospheric humidity, high temperature, and high wind velocity, the transpiration rate becomes very great. If the soil is not abundantly supplied with water, intake is temporarily unable to keep pace with outgo and a so-called "deficit" arises in the tree itself, when various tissues actually shrink and lose in weight, only to be made up a little later when atmospheric conditions are not so extreme. Though these water deficits are of short duration, they occasionally lead to serious consequences (*e.g.*, cork and drouth spot in apples).

Tillage practices that injure or disturb the root system accentuate these troubles. They can be largely avoided by the employment of such cultural practices as tend to provide and conserve the moisture supply and keep it well above the wilting point.

SOIL MANAGEMENT METHODS AND THE MOISTURE SUPPLY

Even where the average rainfall is adequate for the existence of the trees and for the production of crops of home-orchard standard, commercial orchards in many soils require special soil treatments to hold them up to the high crop production required for financial stability. This treatment often takes the form of eliminating all competition from other plants—weeds and grasses—which would naturally grow in the orchard and levy toll upon the moisture and nutrients. There is nothing novel in this system; it has been followed from time immemorial in the culture of "hoed" crops. For orchard work new tools have been devised or old tools adapted; otherwise the apple trees might be cabbages so far as the underlying principles are concerned. This "clean cultivation," in its essentials, is undoubtedly the prevalent system of orchard management; with some fruits it is practically universal. That the system does result in real conservation of moisture has been shown by quantitative measurements in experimental orchards; in some cases the soil moisture content has been from 40 to 70 per cent greater in cultivated soil than in sod, the subsoil containing from 50 to 90 per cent more. This has not been uniformly true, however; in an experiment in New Hampshire the moisture in the cultivated portion was no greater than that in sod and the improved condition of the trees was doubtless due to other factors, such as increased nitrification, which is discussed in another chapter.

Some orchards are located on ground so sloping that the danger of erosion precludes clean cultivation (Fig. 20). Others are located on soil particularly retentive of moisture or in spots where they receive seepage from higher ground; in these, clean cultivation may be unnecessary, for some fruits. Even under these circumstances, full competition from sod is generally detrimental to tree growth, but a partial elimination of sod plants by covering them with mulching material is wholly feasible. Straw may be distributed among the trees; sometimes, indeed, with abundant moisture and high fertilization, frequent cutting of the grass in

the orchard gradually builds up a mulch which at length checks the growth of the grass. In addition, the mulch itself aids in the conservation of moisture by checking run-off and evaporation.

The sod-mulch conserves moisture more effectively in late summer and fall than it does early in the season, when the grass is making some growth. However, through the rest of the season it seems to accumulate a reserve for this period of stress. In any case, it is certain that some of the most successful apple orchards in the country are managed under this system. The

FIG. 20.—A hillside sod orchard, near the Missouri River. Clean cultivation in this orchard would lead to soil erosion and would be very difficult. The great depth of the loess soil diminishes, for old trees, the injurious effects of sod.

higher color of apples grown in sod makes the system particularly desirable, provided growth can be maintained in the trees and size maintained in the fruit. This is being done in many orchards, particularly where nitrogen-carrying fertilizers are used. The system is not, however, enduringly successful in soils which tend to be chronically dry.

WATER SUPPLY AND PLANTING DISTANCE

Occasionally fruit can be grown in very arid regions by reducing competition among the trees themselves. This has been

done in some of the olive orchards of northern Africa. In irrigated sections or where rainfall is ample, olive trees are planted 18 to 20 feet apart. Near Sfax, in Tunis, though the rainfall averages about 9 inches and has been as low as 6 inches for several successive years, a profitable olive industry has been built up without irrigation by growing the trees 60 to 80 feet apart, or only 7 or 8 to the acre. The water requirement per acre has been reduced, though the water requirement per tree or per unit of dry weight has remained the same or conceivably has been increased.

A trip to Tunis is not necessary to provide an illustration of the desirability or necessity of letting the water supply be a guide to planting distance. Examples may be found in every fruit-growing section. Indeed, instances of orchards that have attained middle age with trees in the center as large, thrifty, and productive as those in the outside rows are the exception rather than the rule. Without doubt, an inadequate nutrient supply is partly responsible for this condition but in the great majority of cases lack of water at critical periods during the growing season is the dominant factor. That few growers recognize the condition just described as a symptom of repeatedly recurring drought is probably due to the fact that it is more often a delayed, residual, gradually developing effect than an immediate response to a single dry period, for it is as obvious in the midst of a period of unprecedented rainfall as at any other time.

THE DANGER FROM "WET FEET"

When water is supplied directly through irrigation, too much may be added; excess may be just as disastrous as deficiency. Though plants require water in large quantities for growth, the roots that absorb the water are composed of living cells that must respire. If the supply of oxygen is cut off for any considerable period by a rise in the water table, the submerged roots die. It often happens that trees receiving the heaviest irrigations or those growing on the lowest and perhaps most fertile lands suffer most from lack of water because their living roots are confined by a high water table to a very shallow layer of soil. In running water that is well aerated, roots can live because they can extract the oxygen that is dissolved in the water. Ground water, however, contains very little oxygen in solution and roots will not penetrate a water-logged stratum of subsoil (Fig. 21);

moreover, submerged roots soon die of oxygen starvation. Ordinary fruit plants cannot grow in a soil that is nearly saturated with water. A soil that is half saturated with water is in the best condition for ordinary plant growth. It holds enough water and at the same time enough air.

Much perfectly good agricultural land is poor for fruit trees merely because the water table is high for a part of the year. During the growing season it may be deep enough for plants in general, including trees, and crops planted in the spring and harvested in the fall may never suffer from excess moisture;

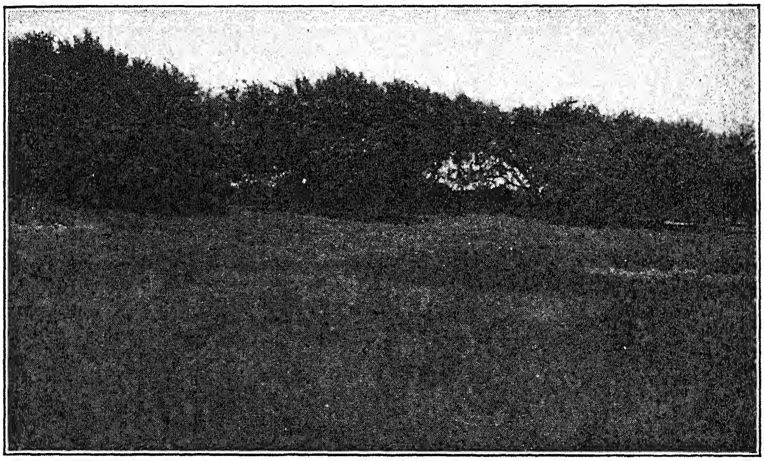


FIG. 21.—Eighty-year-old trees in the background. In the foreground a few feet difference in elevation with an accompanying high water table, has produced a "dead spot."

trees, however, may suffer in the same soil because the water table rises to a high level in late fall or early spring. In many of the deep, "fat" prairie soils, fruit trees are very shallow rooted.

Failure of surface topography to conform to that of the subsoil may raise some difficulties in orchard lands. The surface may slope uniformly, while the subsoil is full of hills and dales. This causes the formation of areas of poor drainage, even on slopes where the surface drainage appears perfect. These "dead spots" are sometimes replanted to trees many times over, when a few feet of tile drain would make one planting suffice. This is well brought out in Fig. 21.

In humid or in arid regions, the best insurance against moisture troubles is the selection of land affording the proper soil conditions. Initial capital outlay for this purpose is cheap in comparison with constant effort at remedy. Good orchard land should be deep, with excellent drainage and a permanently low water table. In a soil of this kind, trees can develop a deep and adequate root system—a root system that makes the tree independent of weekly, seasonal, or even yearly fluctuations in rainfall, fortified against occasional or periodic drought, resistant to winter cold and perhaps less likely to be in constant need of fertilizer applications.

Withal, the studious fruit grower should orient conditions in his own locality with reference to those elsewhere. Of two soils with identical water content, one may liberate more moisture to plant roots than the other; the percentage of availability is likely to be greater in sandy soils than in those containing large amounts of clay. Furthermore, a soil considered fairly moist in one locality might be considered rather dry in another. The scriptural ideal of prosperity, "like a tree planted by the rivers of water," is an excellent simile for the Holy Land, but English and French pomological literature gives no little attention to drainage of orchards. Fruit is grown in the United States under conditions as unlike as those of Palestine and northern France.

CHAPTER IV

THE INTAKE OF WATER AND NUTRIENTS

Many grape vines growing on the marly soils of France and Germany have suffered from a peculiar disorder marked by the loss of green color from the foliage. In England pears, peaches, plums, nectarines, apricots, and cherries standing in soils overlying chalk deposits have sometimes become similarly affected. Citrus trees growing over a marly subsoil sometimes develop the disease, and orange trees in Florida have become affected following the application of large quantities of limestone to the soil.

Various ingenious and successful treatments of this malady have been devised. In Europe, affected grape vines have been cured by painting the cut ends of the canes with a strong solution of iron sulphate after the winter pruning. Satisfactory results have been obtained also by boring holes in diseased trees and filling these with some soluble iron salt. The success of these treatments shows beyond a doubt that a lack of iron is responsible for the disorder in all these cases.

Echoes and fragmentary accounts of these rather striking treatments have sometimes gone the rounds of the agricultural press and readers in northern states whose trees have really been suffering from quite different disorders, have been tempted to try these remedies. Strictly parallel situations in the deciduous fruit plantations of America are comparatively rare. The disease, however, has caused considerable trouble in pear orchards of the northern part of the Santa Clara Valley in California, where the trees affected are on black adobe soil with an underlying subsoil that is highly calcareous. The condition has been alleviated by iron sulphate, applied to the soil or injected into the tree. In a few weeks the leaves regain their green color and, generally the second year after the treatment, fruit buds are formed. Trees thus treated usually revert to the diseased condition in about two years and must receive another treatment. Among subtropical fruits, the disease is more common.

DETERMINING THE CAUSE OF A NUTRITIONAL DISORDER

During the early development of commercial pineapple culture in Porto Rico, many loose, well-drained soils apparently ideal for pineapple, proved to be wholly unsuitable. Although the plants grew to normal size in these soils, the leaves eventually lost their green color, turned pale red or waxy white, and later developed brown spots or red streaks with small patches of green (Fig. 22). They grew slowly, yielded unsatisfactorily, and died prematurely. At first, avoidance of soils where the pineapple became diseased was simple, but as the industry grew, use of

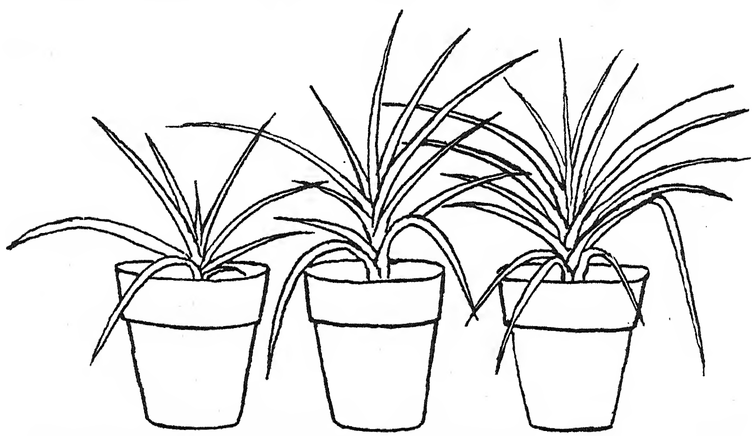


FIG. 22.—The pineapple plant at the left is suffering from chlorosis induced by iron deficiency. The two normal plants to the right have had their iron deficiency relieved by an application of iron sulfate. (*After Gile.*)

these well-located and well-drained soils became more and more desirable.

Salt spray from the sea was considered to cause the disorder, until plants grown well inland were found to be equally affected. The spotted appearance of the leaves suggested a bacterial disease, but affected plants transplanted to good pineapple soil regained their green color in a month or two and remained healthy. Soil analysis revealed little except the presence of rather large amounts of lime. Carbonate of lime added in large amounts to soils in which healthy pineapples were growing produced the disease.

When further study disclosed the fact that the diseased plants contained noticeably less iron than healthy plants, solutions of

iron salts were applied to the soil but they were without effect on the plants. Indeed, no evidence had been found that the soils lacked iron, and some of the best pineapple soils in Florida were known to contain only one-fifth to one-quarter of 1 per cent—less than one-tenth of the amount present in some of the calcareous soils of Porto Rico. Finally the disease was overcome by spraying the leaves with a weak solution of iron sulphate, the same material which proved entirely ineffective when applied to the soil. The disease was thus shown to be a case of iron starvation in the presence of relatively enormous quantities of that element. Though very small quantities are ever required for growth, these very small quantities are absolutely essential, and the pineapple plants seemed unable to obtain these minimal amounts. While many other kinds of plants were unaffected, pineapples were unable to obtain from these calcareous soils enough iron to keep them healthy, though the small amount absorbed by the leaves from the solution sprayed on them was sufficient.

This situation, though it is rather extreme and though it passes ordinary experience with deciduous fruits, is not without some applicability to them. With any nutrient element the difference between the "amount present" in the soil and the "amount available" to the plant is in many cases large and the distinction between them should be kept clear. Much of the amount present may be in an insoluble form and some of that in solution may be unavailable. Chemical analysis of the soil is at present powerless to measure these distinctions and is ordinarily an unsafe guide to soil treatments.

However well this investigation accounted for the inability of the pineapple to grow without the iron sulphate spray, it did not in itself explain their inability to absorb iron from calcareous soils. The absorption from the soil of water and all the mineral salts that plants obtain depends primarily on certain properties of dissolved materials. When salt or sugar is placed in water it goes into solution; if the water is stirred, the dissolving proceeds more rapidly. Without movement of the water, however, the process goes on slowly. The dissolved particles move away from a region where they are numerous toward regions where they are few and in time a dissolved substance becomes evenly distributed.

When the particles of a dissolved material are more crowded outside of a plant than they are inside, they enter the plant if

there is a connection between the soil solution and the plant sap. Absorption continues, therefore, as long as any material is present in the soil solution and as long as the concentration of this substance is lower inside the plant than in the soil. This principle applies not merely to the mineral constituents of the soil but likewise to the water in which they are dissolved. If there is more water in a given volume outside the plant than there is within (in other words, if the soil solution is more dilute than the plant sap) water will flow into the plant. A strong salt solution contains more salt than a weaker solution, but at the same time the weaker contains more water than the stronger. Plant sap is normally a stronger solution than the water in the soil, because it contains, dissolved in it, substances such as sugar and acids and other compounds that the plant has manufactured. Plant sap, therefore, contains relatively less water than the soil solution, in consequence of which water flows readily from the soil into the roots.

If this principle worked universally without impediment the organic substances that maintain the high concentration of plant sap would flow out into the soil by the channel through which water enters, because they are more concentrated within the plant than in the soil solution. Actually, however, the absorbing cells of the root—the root hairs—are so constructed that these organic materials cannot escape, except perhaps with extreme slowness.

It was once thought that the mineral salts of the soil were swept into the plant along with the water and that the plant's part in their intake was entirely passive. In reality, the absorption of a mineral element is to a considerable extent independent of water absorption and is determined by its solubility in the soil solution and the difference in its concentration inside and outside the plant. Indeed, it is possible for the roots of plants to absorb small quantities of nutrient materials without at the same time absorbing any water.

SOIL REACTION AND SOLUBILITY

Can the inability of pineapples to absorb iron from a calcareous soil be accounted for on this basis? Has lime any property that would make iron insoluble? Lime is often added to sour soils to neutralize their acidity and if enough is added the soil can be made alkaline. Limestone soil, however, is not necessarily alka-

line; it may be distinctly acid under certain conditions in spite of a high lime content, but in practically all the cases where plants growing on a calcareous soil show signs of iron starvation, the soil has been found to be distinctly alkaline. When gypsum, which is sulphate of lime, is added to a soil the availability of iron is not affected, but when carbonate of lime is added, iron absorption is impeded. Gypsum has no effect on soil reaction; carbonate of lime reduces soil acidity. The basic reaction of the soil, rather than its lime content, renders the iron unavailable to the plant. In fact, the soil need not be actually alkaline for even in a neutral or very weakly acid solution the solubility of iron is greatly decreased and some plants may be unable to absorb enough for healthy growth. Iron is not alone in this respect. The solubility of other basic substances is similarly affected by a decrease in acidity, though seldom to an extent that interferes seriously with plant growth.

REACTION AND ABSORPTION

The ingredients that the plant takes up from the soil are of two kinds or classes; some are acids, such as sulphuric acid and phosphoric acid; some are bases, such as iron, magnesia, lime, and potash.

In a strongly acid soil acids are absorbed much more readily than bases. In a weakly acid or basic solution the basic elements are absorbed in greater quantities. No soil is absolutely homogeneous throughout. When the root reaches the more acid spots the acids are extracted and from less acid areas bases are absorbed. The result is that the plant obtains all the elements essential for growth.

One essential element, and only one, can be obtained both as an acid and as a base. This is nitrogen, which may be absorbed either as ammonia or as nitrate. It so happens that of the two chief nitrogen-containing fertilizers, one carries acid nitrogen as nitrate of soda and the other carries basic nitrogen as sulphate of ammonia. Plants growing on a very sour soil absorb nitrates more readily than ammonia while plants growing in a weakly acid or in a basic soil should absorb ammonia more quickly. Plants on a calcareous soil may respond better to an application of ammonium sulphate than to an equal amount of nitrogen in the form of nitrate of soda.

The effect of continued fertilization with nitrate of soda for, say 20 years, offers an interesting problem. The trees absorb the nitrate in the relatively large quantities essential for growth. The soda, however, is not essential and though some of it may be absorbed most of it is left in the soil. Ordinarily, much of it leaches out of the soil because it is very soluble, but in an arid region it may accumulate, making the soil solution alkaline and

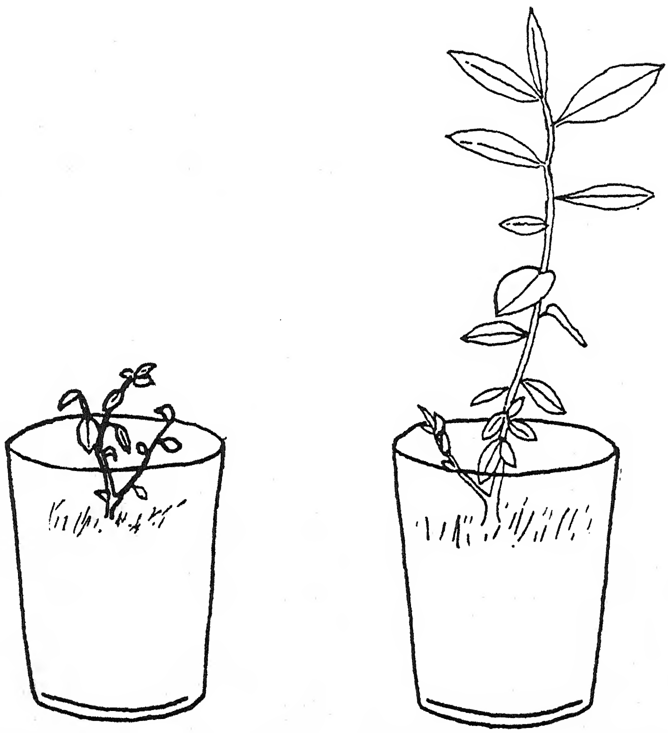


FIG. 23.—Two blueberry plants grown in peat soil. That at the left was limed to give it a neutral or basic reaction. (*After Coville.*)

eventually the same condition that has been observed on some limestone soils is likely to develop. The iron may become insoluble and the plants diseased. This is exactly what has happened in some of the orange groves of California where nitrate of soda has been used continuously for many years.

The continuous use of sulphate of ammonia has just the opposite tendency. The soil eventually becomes acid. Applications of nitrate of soda would be more effective on an acid soil

and would counteract an excessive soil acidity, though marked effects would be obtained only after a long series of years. Similarly, sulphate of ammonia would be absorbed better from an alkaline soil and would gradually correct this basicity. The harmful effects of a continuous use of either of these fertilizers may be counteracted by the use of the other.

Soil acidity occasions the general farmer much concern. Many crops do not grow well in sour soils and lime must be added to correct their acidity, but most fruit plants are distinctly acid tolerant. Strawberries, blueberries (Fig. 23), and the brambles do best when the soil is rather acid; even oranges grow well under these conditions. It is fortunate and perhaps not without reason that the best orchard cover crops are also acid tolerant. Cowpeas, soybeans, hairy vetch, crimson clover, rye, oats, millet, and buckwheat grow well in orchard soils that are somewhat sour. As a rule it is not necessary to correct soil acidity in an orchard, as far as the fruit trees are concerned, though there are exceptions. The cherry seems sometimes to respond favorably to lime applications. Moreover, liming occasionally has a place in orchard management because it often promotes the growth of intercrops or of the plants forming the mulch in a sod-mulch orchard. If these are turned under and used as green manure or if they are mowed and allowed gradually to decay, the trees benefit ultimately.

STARVATION RATIONS

One more condition must be fulfilled before a substance soluble in the soil solution may be absorbed by the roots. Its concentration within the plant's sap must be less than its concentration in the soil solution, or, stated the other way, its concentration in the soil solution must be greater than that in the plant cell. A soil may be so "poor," a soil solution may be so dilute, that the plant cannot secure some required nutrient from it. Wheat has been grown, however, in water from the Potomac River, an extremely dilute salt solution. This water contains only 2 parts of phosphoric acid per million of solution. Few plants could be found that do not contain at least 50 parts of phosphoric acid per million of their fresh weight. How, then, can phosphoric acid be absorbed? If all the phosphoric acid in the plant were dissolved in the cell sap, no more could be taken in, but the essential mineral salts absorbed from the soil are used for growth.

They combine with the organic matter produced in the leaves to form the plant substance. As a result they are removed from the cell sap, its concentration is lowered, and room is made for more inorganic salts to flow into the plant from the soil. In this way the utilization of soil constituents for growth makes possible their continued absorption and the "poorness" of many soils is due to factors other than the low concentration of nutrient materials.

Many elements in the soil solution that are not essential for growth enter the plant. There is no reason why they should not be absorbed until their concentration inside the plant becomes as great as in the soil solution. If they should combine with any of the organic constituents of the plant to form insoluble compounds, the flow of these elements into the plant would continue so that they might accumulate in considerable quantities, as often happens. The continued absorption of any element depends on its ability to combine with the organic material of the plant or to be altered in some other way that removes it from solution. It is through utilization or non-utilization of the materials absorbed by the roots that the plant effects what is known as "selective absorption," the absorption of substances in proportions entirely different from those existing in the soil solution. Useless, little-used or even harmful materials may be absorbed in small quantities by the root hairs, but, not being utilized, they may be held there "in quarantine," an effective barrier against the entrance of more of their kind. On the other hand, certain harmful substances, such as some of the soluble salts of copper and arsenic are taken in freely. Some materials, however, when present in the soil solution in high concentration, are able to penetrate into the plant in large enough quantities to produce injury or even death. The sulphate, carbonate, and chloride of sodium, present in so-called alkali soils, sometimes do this. Overdoses of some fertilizers, such as acid phosphate and sulphate of ammonia, affect plants in a similar way. Injuries to fruit trees from excessive concentrations of these salts occur chiefly in arid or semi-arid sections where orchards are irrigated with saline waters or where rainfall is insufficient to leach out accumulations of salt residues, but are not unknown in humid regions, particularly in dry summers. Heavy applications of chemical fertilizers are most likely to occasion injuries of this type in shallow-rooted plants such as the strawberry. Areas that have become barren because of a gradual accumulation of soluble

salts are reclaimed most readily by heavy and repeated irrigation with non-saline water which dissolves and carries away a portion of these injurious substances.

Salts of the heavy metals usually produce effects that are out of all proportion to the amounts actually absorbed by the plant. Exceedingly minute quantities may be poisonous and may induce disturbances that lead to death. The free use in spray materials of compounds of copper, lead and arsenic has occasioned much uneasiness among growers who have feared that their fruit plants might be endangered by accumulations of these materials in the soil. There is, to be sure, a considerable accumulation in the surface soil of spray materials, such as arsenate of lead, which are used year after year, but indications of injury that can be traced definitely to this factor are very rare and in most sections entirely lacking. Experiments designed to test the actual danger involved indicate that it is generally insignificant.

The heavy metals are not always poisonous. They are sometimes powerful stimulants. This seems to be the case when the amounts absorbed by the plant are less than those producing toxic effects. Apple trees and grape vines sprayed with Bordeaux sometimes show a luxuriance of growth that can be attributed only to the absorption of minute traces of copper through the surface of the leaves. Similar effects have been produced in grapes by the injection of copper salts into the trunks, a delicate experiment, as a slight overdose is likely to prove fatal. In this respect there is a great difference between kinds of fruit plants and also between varieties. York and Duchess, for example, are relatively resistant to copper poisoning and might be stimulated by amounts that would produce toxic effects on more susceptible varieties of apples such as Jonathan.

Some evidence has been found to show that manganese, zinc, and boron applied to annual crops in small amounts sometimes have a stimulating action analagous to that of copper just described. Similar results with fruit plants have not been reported.

CONTROLLING ABSORPTION

Absorption, obviously, is a plant function over which man has no direct control. He should, however, remember that roots cannot absorb from the soil what is not there in an available form, and they are not able to exclude all substances that are

harmful or poisonous. Nutrient materials can be absorbed rapidly and in large quantities only when they are present in relative abundance. To see that throughout the growing season the soil contains sufficient quantities of nutrient materials in an available form means in practice attention to the nitrate supply, for seldom is there a deficiency of other nutrient materials. Determination of the quantities present in the soil by chemical methods is, of course, out of the question. Fortunately this is unnecessary because the appearance of the plants themselves is a fairly good index of the way in which they are being supplied.

In general, increasing the supply of nitrates or of other nutrients is a relatively simple matter. Tillage, the growing of leguminous intercrops, cover crops, or mulching crops, and the use of fertilizers are methods that are at once suggested. Reducing the supply of soluble salts is often a more difficult matter. Care in irrigation and in disposing of wastes from spraying and moderation in the use of fertilizers often aid materially in preventing surpluses accumulating to the danger point.

CHAPTER V

THE NITROGEN SUPPLY

During the first decade of this century, throughout southeastern Ohio, as well as in many other states, hundreds of orchards stood neglected. Had it been spring, the traveler seeing the white and pink of the blossoms set off by the fresh green of the unfolding leaves might have wondered at this neglect, but this heavy bloom, for all its beauty and fragrance, was an empty promise. These plantations in the pioneer orchard area of Ohio did not yield enough apples even to supply the scattered population that struggled to wring a bare subsistence by grazing sheep among the trees. A trained eye might have noted signs of previous attempts to crop the soil, but the denuded hill slopes were then covered with a sparse growth of poverty grass and made but poor browsing for a few sheep. The owners had long since come to disregard the feeble trees that each year made but a puny growth, covered with yellowish-green leaves, except as objects to furnish shade for their stock.

NITROGEN EFFECTS A TRANSFORMATION

A few years later, in the fall, long lines of wagons heavily laden with apples made their way from these hills to the shipping stations. Freshly painted barns and here and there a new house bore witness to a revived prosperity. It would have been difficult to believe that the vigorous trees covered with dark green foliage were the same sickly plants that had stood there a few years before, barely able to exist. It would have been still more difficult to believe that this remarkable transformation in so brief a period had been brought about by the yearly application to each tree of a few handfuls of fertilizer containing nitrogen. So striking was the change in the trees, and in the communities as well, and so simple, inexpensive, and apparently insignificant was its cause that the whole situation resembled the fabulous exploit of some magician rather than a prosaic demonstration in orchard soil management. The remedy appeared to act more

as a powerful stimulant than as a mere nutrient. To be sure, this transformation was not accomplished without the aid of

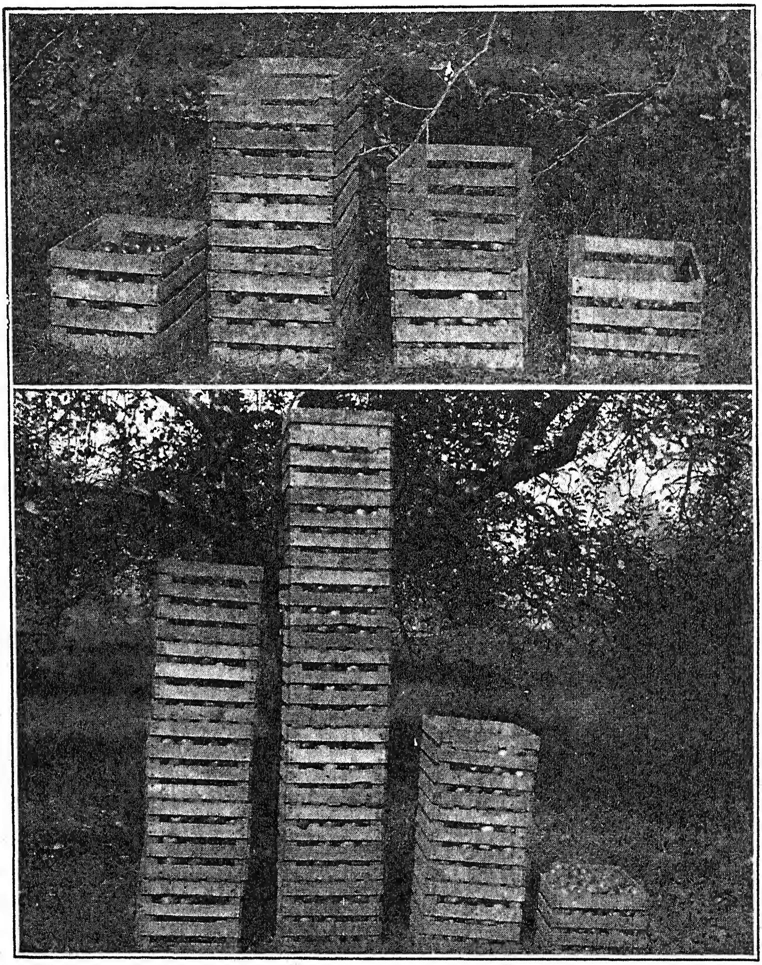


FIG. 24.—*Above.* Crop from an average 45-year-old unfertilized apple tree growing in sod. *Below.* The crop from an average tree of the same age and variety but fertilized with 5 pounds of nitrate of soda. The stacks of crates, reading from left to right, are of 2¾, 2½, 2¼ and less than 2¼ inch sizes, respectively. Note that fertilization has had nearly as great an influence on average size as on total yield.

thorough spraying, but spraying alone had previously produced little positive improvement. The remarkable change must be attributed primarily to the use of nitrogen-containing fertilizers

on the plow-worn, rain-washed soil, impoverished by thoughtless cropping.

Experience has shown that more orchards respond to applications of nitrogen in some form than to any other element. In fact, from Maine to Oregon, wherever fertilizer applications have materially increased fruit yields, almost without exception nitrogen alone has been of value. For all practical purposes the fertilizer problem in fruit growing is a nitrogen problem. This seems somewhat surprising when it is recalled that the air is nearly four-fifths nitrogen gas and that this immense reservoir of nitrogen literally bathes the very plants that suffer from an insufficiency of it. It is all the more remarkable in view of the fact that the nitrogen of the atmosphere is the ultimate source from which all the nitrogen found in soils and in the tissues of plants and animals has been derived. It was in 1838 that the celebrated French agronomist, Boussingault, showed for the first time that the higher plants obtain their nitrogen supply from the soil and not from the air and it was not until about 1910 that serious thought was given to possible nitrogen deficiencies in orchard soils.

NATURAL AND ARTIFICIAL SOURCES OF NITROGEN

Although fruit trees are unable to utilize directly the gaseous nitrogen of the air, there are organisms that have this power. Certain soil bacteria and a few fungi convert nitrogen gas to nitrates, a form of nitrogen that can be absorbed and used by the higher plants. Nitrates are produced also in some way as a result of natural electrical discharges in the atmosphere, a process of some interest because a similar procedure is now used in certain manufacturing establishments to convert atmospheric nitrogen to commercial fertilizer. The amounts of nitrate that are made naturally by this process in the air and brought down to the earth in rain are relatively small, the maximum per year under the most favorable circumstances being about 5 pounds to the acre. This would barely meet the requirements of one apple tree of medium size. Bacteria must be relied upon for the fixation of atmospheric nitrogen in significant quantities.

Of the several kinds of bacteria and fungi that fix the elusive nitrogen of the air—and more and more are being found to have this property—only one group is of great practical importance. These are the bacteria that live on the roots of clover and other

legumes, such as peas, vetches, and alfalfa, in the nodules peculiar to this family of plants. The nitrates that these bacteria make are utilized by the leguminous plant in the manufacture of proteins and other organic compounds containing nitrogen. Herein lies the principal value of clover and other legumes both as forage and soil-improving crops. Possibly it is this property that makes trees grow better in a clover or alfalfa sod than in a bluegrass or timothy sod.

Domesticated plants and animals are familiar elements of our civilization; domesticated bacteria are rather an innovation in our experience. Successful agricultural practice, however, is so intimately connected with various types of bacterial activity, that the desirability of domesticating them is apparent. Of late years, this has been done and nitrogen-fixing bacteria are now used to inoculate soils.

How does the tree obtain the nitrogen contained in the nodules, roots or tops of the legume which composes the sod surrounding it? The nitrogen-containing protein and the other organic substances into which the legume has converted the nitrogen supplied it by the bacteria living on its roots, are of little more direct value to the tree than the gaseous nitrogen that comprises 78 per cent of the atmosphere. At this point, however, another group of bacteria that live in the soil come to the rescue. These are the organisms largely responsible for the decomposition and putrefaction of dead plant tissues and, though their activity frequently results in the liberation of many ill-smelling substances, it also leads to changes in the condition of organic nitrogen that are of great agricultural import. The clover proteins are broken down and the nitrogen is split off as ammonia. A little of this ammonia is absorbed by the roots of the trees; some escapes to the air and is lost to them except for small amounts which may be washed down again by rain; still more remains in the soil and is acted on by another kind of bacteria.

CONDITIONS FAVORABLE FOR NITRATE FORMATION

Bacteria of the third class convert ammonia first to nitrites and then to nitrates and so bring nitrogen to a form that can be used freely by apple trees and other fruit plants. Though nitrogen in the form of ammonia can be absorbed directly and fruit plants obtain some of their nitrogen supply in this way, nitrates seem to be a more important source of nitrogen and represent a

large part of the supply that most plants obtain. The nitrifying bacteria, as these nitrate-producing organisms are called, have been considered so important that a great amount of time has been devoted to learn the conditions under which they work best. It has been found that they require moisture, moderate temperatures, and plenty of fresh air. Under ordinary conditions they are present in larger numbers and are most active during late spring and early fall when the soil is neither extremely hot nor very dry. During the winter and the driest and hottest part of the summer they are inoperative or less active.

FIG. 25.—Two rows of 7-year-old Montmorency cherry trees, one has been under a clean culture—cover-crop system of soil management while the other has been in alfalfa sod. Nitrogen-containing fertilizers have been applied annually to the sod-grown trees but not to those under cultivation. The difference in size of these trees indicates that the cherry does not thrive with sod culture (compare with Fig. 26).

Nitrifying bacteria are also more active and their numbers increase when the soil is well aerated; hence tillage improves the conditions under which they thrive and leads to a greater nitrate supply in the soil. Increased nitrification and moisture conservation are the main reasons for cultivating the orchard and in some cases, as shown by experiments in New Hampshire, increased nitrification is the more important of the two. Orchards that are so maintained under a sod system of management that the moisture supply is adequate require more frequent and heavier applications of nitrogen-carrying fertilizers than those that are cultivated. In many soils all that is needed to furnish orchards

an adequate supply of nitrates is cultivation. In others, however, either the supply of organic nitrogen is so limited or other factors influencing nitrate formation are so unfavorable that cultivation alone does not make available an amount adequate for the tree's requirements.

Though the general effect of cultivation is to make the soil more fertile, through promoting nitrate formation, in the end it may lead to its impoverishment. This has been a common experience in arid sections where orchardists, recognizing the value of tillage, practiced it for a considerable period of years and then found their trees gradually becoming starved. Investigation has shown the trees were suffering from an insufficiency of nitrogen, the very element that cultivation serves to make available to the plant; the soil was "burned out" and had to be placed under a different system of management. Cultivation does not ordinarily increase the total nitrogen content of the soil; it merely aids processes that convert whatever organic nitrogen may be there to a more available form. Since both ammonia and nitrates are very soluble and when once formed are leached out of the soil unless absorbed, cultivation really depletes the nitrogen supply of the soil.

COVER CROPS AND THE NITRATE SUPPLY

In the main, excessive losses through leaching can be avoided by growing crops which take up the surplus nitrogen and return it to the soil in organic form when they are plowed under. A crop grown for this purpose is called a cover crop; it is sown in the summer, covers the ground during the winter and is turned under in the spring. As it grows in late summer and fall it takes up nutrients and moisture which are unnecessary and perhaps even detrimental to the tree, thus conserving the nitrogen supply and checking tree growth in preparation for the winter. The same crop sown in the spring would have a similar effect but, exerted at the wrong time, the effect would be injurious to the trees. A leguminous cover crop, other things equal, may be somewhat more desirable than one of some other crop plant, inasmuch as when turned under it actually increases the total nitrogen content of the soil, having drawn to some extent for its growth on the ultimate source, atmospheric nitrogen. If seasonal or soil conditions are such that the legume does not make a rank vigorous

growth before cold weather sets in, however, a non-leguminous plant that will make considerable growth better answers the specifications of a good cover crop. The relative cheapness of nitrogen-carrying fertilizers has diminished the importance of nitrogen-fixing properties in cover crops, though it has not affected the general usefulness of these crops in the orchard.

FIG. 26.—Two rows of 7-year-old apple trees; one has been under a clean culture—cover-crop system of soil management, while the other has been in alfalfa sod. Nitrogen-containing fertilizers have been applied annually to the sod-grown trees but not to those under cultivation. There is little difference in size between the two groups of trees. Obviously the apple tree takes kindly to sod culture (compare with Fig. 25).

COMMERCIAL NITROGEN-CONTAINING FERTILIZERS

Though the productivity of many orchards can be maintained by cultivation, by growing clover, alfalfa or vetch for green manuring, or by a combination cultivation-cover crop method of orchard management, in many cases vigorous growth and large yields demand additional soil treatments in the form of direct fertilizer applications. For untold centuries animal refuse was practically the only known fertilizer. Even now well-rotted stable manure is one of the best fertilizers for fruit plants, since animal excretions contain nitrogen in organic form that becomes available after decomposition. At present, however, manure is relatively expensive and its use in commercial orchards is often out of the question. Fortunate indeed are those growers so located that stockyard refuse may be had at low cost. One of the most important substitutes for barnyard manures for orchard use is Chile saltpeter, commonly known as nitrate of soda. The

large deposits in northern Chile, representing accumulations left by the activity of countless nitrifying bacteria through long geologic eras, are the only natural supply. Nitrate of soda, however, now has to compete with a number of other compounds of nitrogen. The most important of these is ammonium sulphate, a by-product in the manufacture of coke and gas.

These compounds are alike in that they are both quickly available. They vary in the amount of nitrogen that they contain and hence in the quantities in which they should be used. Nitrate of soda contains 15 to 16 per cent of nitrogen, depending on the amount of moisture it has absorbed; sulphate of ammonia contains 20 to 21 per cent. Since their value as fertilizer is approximately equivalent to the amount of nitrogen contained, 5 pounds of sodium nitrate produce about the same results as 3¾ pounds of ammonium sulphate. These are the amounts that would ordinarily be used on a fair-sized apple tree showing distinct signs of nitrogen deficiency. Various standards are in use to estimate the approximate amounts required. One rule is to use ½ pound of nitrate of soda for each inch of the tree's diameter; another is to use ¼ pound for each year of the tree's age. The amount that should be used depends principally on the condition of the soil and the size and vigor of the plant; 3 pounds of nitrate of soda or 2½ pounds of sulphate of ammonia suffice for an ordinary large peach tree that shows distinct signs of nitrogen deficiency.

NITRATES ARE IMPORTANT IN THE FRUIT-SETTING PROCESS

The original intention in using commercial fertilizers containing nitrogen was merely to supply nitrogen in an available form where it might be required. To all intents and purposes the fertilizers were nothing but substitutes for well-rotted stable manure and actual field practice has shown that in most respects they serve this function in an admirable manner. On account of the rapidity with which their nitrogen becomes available they can also be made to do things for which the slowly available manure is entirely unsuited. The use of one of these special commercial fertilizers was discovered in a rather curious way. An imaginative investigator once conceived the idea of dissolving nitrate of soda in water and spraying it on apple trees early in the season. In the course of the experiment it was

noticed that a much larger percentage of the blossoms set and developed into apples on the sprayed trees than on those left unsprayed. Later, similar results were secured when the same material was sprayed on the ground. This has since been found to be a characteristic response of fruit trees of several kinds to quickly available nitrogen fertilizers applied to the soil 10 days or 2 weeks before the first blossoms are expected to open and this effect is so important that fertilizing of apples, pears, peaches, and most other fruits is generally done early in the season, that the advantage of an increased set may be obtained. Practically the whole increase in yield obtained the first year after a nitrogen application is due to this increased set. With certain kinds of fruit trees, such as peaches, which ordinarily set a larger crop than they can develop properly, and therefore must be thinned, a nitrogen application before blossoming may increase the work of thinning the crop later in the season. When the object of fertilization is to further fruit development, rather than increase the set, fertilization may be delayed until blossoming is over. This practice has particular advantages where late spring frosts make crop survival a speculative matter.

In many cases a single nitrogen application does not exercise its full effect in the first season. In peaches, besides affecting set and size of fruit, it is likely to increase growth and at the same time to increase the number of fruit buds formed for the following year's crop. In the apple the increased growth immediately following the application leads to the laying down of more lateral buds, with a resultant increase the following year in the number of spurs, which is likely to lead the third year to an increased number of blossoms and of fruits. In this case the increase in number of spurs is in effect a permanent gain in fruitfulness.

DAMAGE FROM OVER-FERTILIZATION

In the right place and at the right time, nitrogen fertilizers are of inestimable value to the fruit grower and their use is, by and large, a phase of orchard management second in importance only to spraying. Nevertheless they may produce results that are not at all desirable. An injudicious use of nitrate or of ammonium sulphate, aside from inducing direct injury, particularly in dry seasons, may lead to excessive production and may accentuate irregular bearing in some fruits such as apples. Excessive

applications might even throw a tree out of bearing entirely, by producing in the tree nutritive conditions closely comparable to those found in immature trees not yet of bearing age. Prolongation of growth late in the season may cause the trees to enter the winter particularly susceptible to severe cold. In the rejuvenation of old orchards, rather severe pruning is often desirable; this treatment in itself induces the development of vigorous new shoots. When trees already stimulated by severe pruning receive an additional impetus to growth from nitrogen fertilizers, winter injury may almost be expected.

Another danger accompanying excessive applications of nitrogen-carrying fertilizers arises from their influence on fruit coloration. Though moderate applications do not greatly stimulate growth and may induce the development of brighter colors, heavy applications that notably increase size and number of leaves and consequently increase the density of their shade, have the opposite effect. This is especially true in apples, pears, and peaches whose fruits require exposure to direct sunlight to color properly. For this reason heavily fertilized trees require more careful pruning than those growing less vigorously. The color of plums, grapes, and some other fruits is not affected by the use of fertilizers.

Still another important influence of nitrogen-carrying fertilizers is that on the season of maturity of the fruit. Nitrogen-treated trees usually mature their crops a week, 10 days or 2 weeks later than those not fertilized. This may or may not be an advantage, depending on the kind of fruit and on market conditions. Excessive crops, however, which are slow in ripening, may be advanced in maturity by this same treatment. With some fruits, as sour cherries, heavy nitrogen applications generally lead to an uneven ripening and caution should be exercised with these fruits, since this may occasion considerable expense in making two or three pickings.

The orchardist naturally avoids any practice that injures his trees or decreases their yields, but more than that he should make sure that the money spent on fertilizer brings a profit. To apply fertilizer where or when it is not needed is a loss to the grower just as surely as is the destruction of a tree. At one time so-called "complete" fertilizers, containing potash and phosphorus, as well as nitrogen, were advocated and rather commonly used. There was a tradition which still persists in some quarters, that potash

improves the color of the fruit and that phosphorus increases yields. Many years of careful experimental work were necessary to correct these false notions. At present nitrogen is recognized as practically the only element in a complete fertilizer that has any direct value for fruit trees, though mixed fertilizers are sometimes beneficial on peach trees grown in practically pure sand. Applications of phosphate may increase the growth of cover crops which are then turned under in the spring to serve as green manures. In this way the fruit trees receive an indirect benefit from phosphoric fertilizers, particularly where a legume is used as the cover crop. Even liming might prove profitable under some circumstances, for the same general reason.

Though the difference in the fertilizer requirements of orchard trees as compared with those of annual crop plants is due principally to the fact that they are woody perennials and consequently present differences in physiology and seasonal life history, doubtless one factor of some importance is the difference in their root distribution and consequent feeding habits, together with differences in the distribution of nitrogen and the other mineral elements in the soil. The roots of most crop and garden plants are limited largely to the surface layers of soil; those of orchard trees range much deeper. Phosphorus, potassium, and the other minerals occur in the subsoil as well as near the surface; nitrogen, on the other hand, is found principally in the organic matter which is a surface soil ingredient. In consequence trees exhaust their available nitrogen supply long before they do their supply of the other mineral elements; with crop plants the other elements within range of their roots and in available form are exhausted as soon as the nitrogen.

It is just as important to know when nitrogen should not be applied as to know when it is required. Used at the wrong time or in the wrong place it will yield no greater returns than potash or phosphorus. In the fruit regions of western New York beneficial effects from nitrogen applications in the orchards are not commonly realized. Nitrogen applications must be used sparingly if at all in apple and pear orchards that are badly infected with fire blight, since vigorous-growing trees are most susceptible to this disease. This susceptibility does not hold with most other diseases. Increasing the vigor of growth is an effective aid in fighting blister canker and black rot canker in apples, and bacterial shot-hole in peaches.

SYMPTOMS OF NITROGEN STARVATION

Yellowish-green color in foliage accompanied by feeble growth is often an indication of nitrogen starvation. Premature loss of leaves in the fall or failure of blossoms to set fruit are other symptoms. These conditions may arise, however, from other causes. Pale green leaves that drop prematurely and weak growth may result from an insufficiency of water, from the attack of borers, and from other causes, and conditions must be ideal for proper self- or cross-pollination before a failure of the young fruit to set can with certainty be attributed to a lack of nitrogen. The necessity for fertilizer treatment is determined sometimes by a process of elimination whereby more obvious troubles are first set aside. On the other hand, the absence of any pronounced symptom is no proof that the trees will not respond favorably to nitrogen treatment.

Perhaps the surest way to tell whether an orchard will respond to fertilizer applications is to experiment with a few trees before trying it on the whole orchard. Even though a deficiency of nitrogen has been clearly shown, the use of fertilizers may not be the best way to meet it. Sometimes cultivation is all that is required. If circumstances demand that the orchard be kept in a grass sod, it is a safe assumption that nitrogen-carrying fertilizers can be used advantageously, though sod orchards on fertile, well-watered bottom land may do as well without them.

No other nutrient element, indeed no other single factor of their environment, so profoundly influences fruit trees as nitrogen. It is, in more respects than one, the key to their composition, their growth, and their production. Fortunately it is a key always in the grower's possession, for nitrates and ammonium sulphate can always be procured and are always relatively inexpensive.

John Evelyn, who "first taught gardening to speak proper English," wrote in 1675: "I firmly believe that were saltpeter to be obtained in plenty, we should need but few other composts to meliorate our ground," a conviction that has received rather startling justification as far as fruit culture is concerned, though it was to be a century and a half before a saltpeter was obtained in plenty from Chile and nearly another century before non-nitrogenous fertilizers were recognized as unnecessary in the orchards.

CHAPTER VI

GROWING AND FRUITING HABITS

For many years French horticulturists have classified twigs of fruit trees into various types, each with a name and definite expectation of fruitfulness or of barrenness, as the case may be. In 1701, Liger, one of the earlier writers on the subject, recognized four kinds: the fruitful, the hopeful, the barren, and the watersprout; later classifications are more elaborate. A fundamentally different set of economic and natural conditions has kept American fruit growers from attempting the minutely detailed pruning that focuses attention on these peculiarities of type and has led them to overlook some benefit they might have secured from a more careful scrutiny of individual trees. Though it is quite true that American fruit growers cannot afford to employ the niceties of highly intensive fruit culture as they relate to pruning, it is equally true that some of them expend considerable labor in removing the very twigs which are the most productive. A three-dollars-a-day man with a set of pruning tools can easily cost his employer twenty-five times his wage, or even more if he is sufficiently industrious. Though he does not know the difference between a *dard* and a *brindille*, any apple grower should know enough of the fruiting habits of his trees to keep him from wholesale raking of fruit spurs from the branches to make them "look neat and shipshape;" actually there are many whose orchards are, by this standard, neater than they are fruitful.

Beyond its applicability to pruning, knowledge of fruiting habits may be even more useful in providing a standard to which individual trees may be compared, by which any deficiencies may be measured, and through which remedial treatments may be suggested. When the grower can go from tree to tree and read on the twigs the records of growth made and fruit borne for several years back, he has better material to inform him about the cultural needs of his own orchard than he could secure from the most elaborate chemical analyses, and as he grows in skill

he will learn to associate growth conditions with tendencies and thus he will be able to anticipate requirements.

The Tree Record.—When growth stops for the season, all the common deciduous fruit trees ordinarily form, at the end of each twig, a bud, which, because of its position, is known as the terminal bud. This bud contains the growing point and some rudimentary leaves; its exterior is composed of scales (Fig. 12). When growth is resumed in the spring the bud opens, the leaves it contained enlarge and unfold, the young shoot emerges, and the scales drop off. Scars mark the places where the scales were attached; ordinarily these scars, each rather long and narrow and extending at right angles to the axis of the stem, are grouped in a rather clearly defined zone which extends around the twig. Since this zone marks the end of one season's growth and the beginning of another, it is known as the annual ring, though perhaps some other name, such as "external annual ring," would be less confusing. Occasionally twigs make a "second growth," *i.e.*, have two distinct growth periods in one season, but the rings formed in these cases are incomplete and readily distinguished from those that mark the termination of the growth for winter. Ordinarily these rings remain rather well defined for several years, except on extremely vigorous shoots, and render possible the measurement of the growth made each season for some years previous.

HOW THE APPLE BRANCH COMES INTO BEARING

In the apple the leaves on moderately vigorous shoots of the current season's growth occur singly. In the angle between each leaf stalk and the shoot to which it is attached is a bud, sometimes called an axillary bud, though this term loses its significance when the leaves fall, and the term "lateral" is always applicable. There is some difference in the development of these buds; those near the base of the year's growth are generally rather small, while those at the tip are prominent in a well-ripened shoot, but poorly developed on immature wood. Once these buds are formed there is little external evidence of any change in them during the same season; at the approach of winter the leaves fall and the buds are ready for winter.

A forecast of the future of these buds can be derived from inspection of the previous year's shoot growth. Here it is apparent that those which a year ago were simple lateral buds, more or

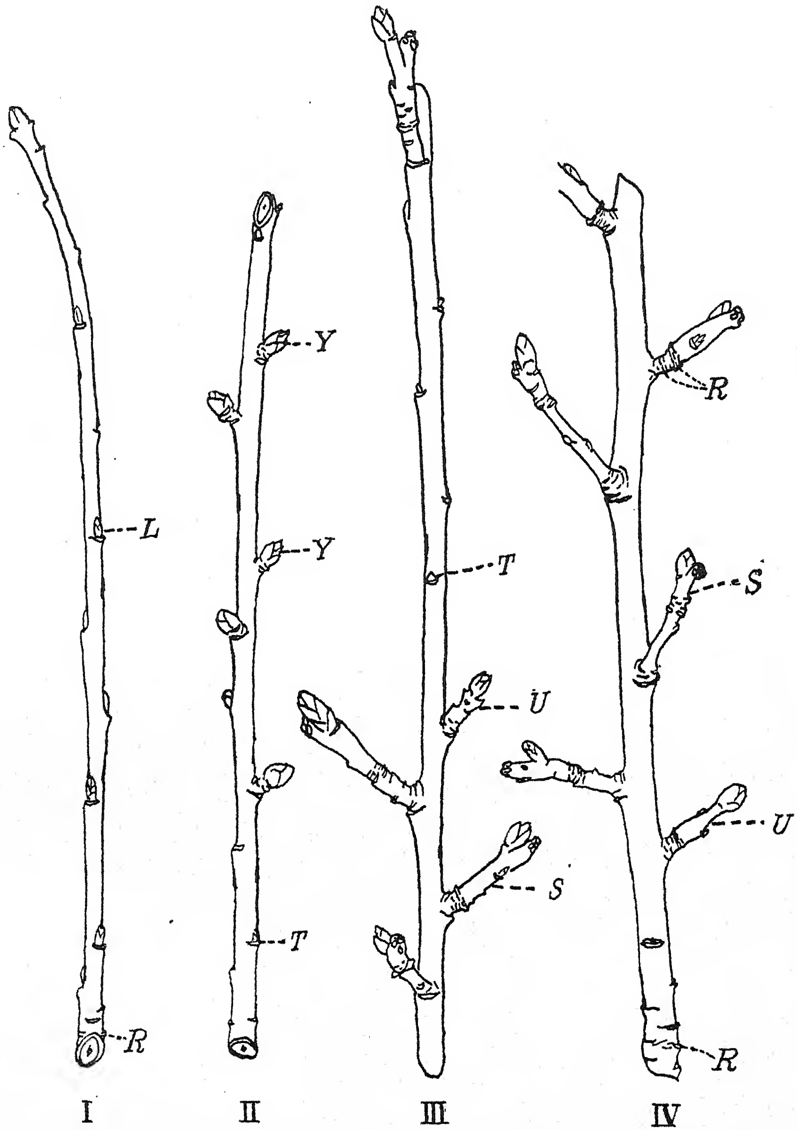


Fig. 27.—Three years' growth in a shoot on a vigorous apple tree: (I) latest growth; (II) "1-year-old" wood; (III), (IV) "2-year-old" wood; *L*, lateral buds; *T*, latent buds; *Y*, young spurs; *S*, spurs which have fruited; *U*, spurs which have not fruited; *R*, annual rings. Nine spurs have blossomed.

less alike, have behaved in somewhat different ways. Some (Fig. 27) have stood still or "latent;" these probably never will develop, unless some accident, such as the breaking or cutting of the shoot just above them, forces them into growth. They are, in a sense, reserve buds. From other buds have grown out short lateral twigs called spurs.

Examination of the shoot between the second and third external annual rings shows these spurs when they are a year older. Each has an annual ring, signifying two seasons' growth. Some of them further differ from the younger spurs in possessing club-

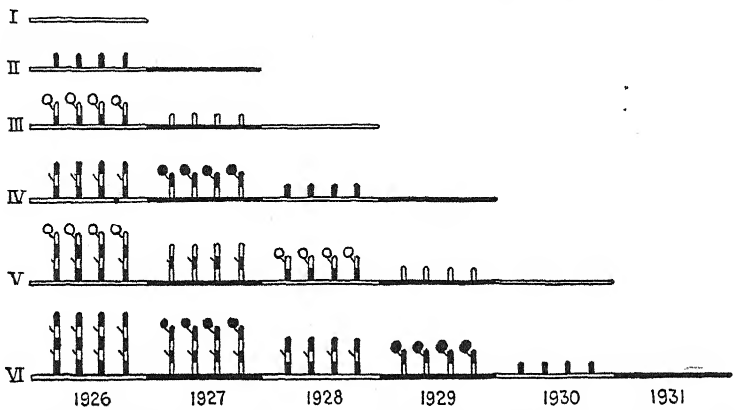


FIG. 28.—Diagrammatic representation of ideal fruiting habit in apple. Six years' growth of one branch are shown. Solid lines represent growth of odd (or even) and unshaded the growth of even (or odd) years. Circles represent fruiting; shading, or lack of it, corresponds with wood growth. First year, shoot growth (*cf.* Fig. 27); second year, spur formation and shoot growth; third year: fruiting, formation of new spurs, and shoot growth; fourth year: spurs resting, spurs fruiting, new spur formation, and shoot growth.

shaped swellings (called "purses" or "cluster bases"), each with a bud on the side and near the end, while the summit of each has a group of more or less circular scars; these scars vary in size, the smaller indicating the point of abscission of a blossom or a very small fruit, and the larger indicating that the fruit approached or reached mature size.

Here, then, spurs in their second year, on shoots in their third year, have borne fruit. The successive stages have been: first season, lateral bud; second season, young spur; third season, fruiting spur (Fig. 28).

The presence of a bud on the spur promises continuation of growth in years subsequent to fruiting. This is actually the

condition that exists. An apple spur may grow relatively little, but bear for many years (Fig. 29). In most varieties, however,

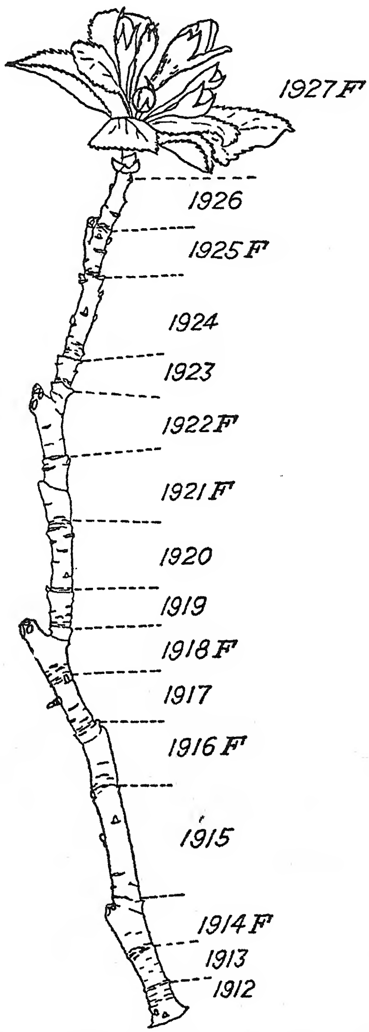


FIG. 29.—Seventeen-year-old spur from apple tree. Each season's growth indicated. *F*, denotes blossoming and possible fruiting. Seven blossom buds in 17 years.

fruiting of the same spur in consecutive years is uncommon; the normal condition is alternation, *i.e.*, fruit one year and purely

vegetative growth the next. In other words, lateral buds on a shoot growth of an even year form spurs which bear in the next even year and in succeeding even years (Fig. 28). Similarly the shoot growth of the odd years forms spurs which bear in the odd years, in the ideal tree.

HOW THE APPLE TREE COMES TO BEAR BIENNIALLY

The ideal apple tree, then, should bear a crop every year and at the same time make sufficient growth to provide for future crops. Actually this condition is not fully realized, even in trees which are bearing annually; the departure is due chiefly to the

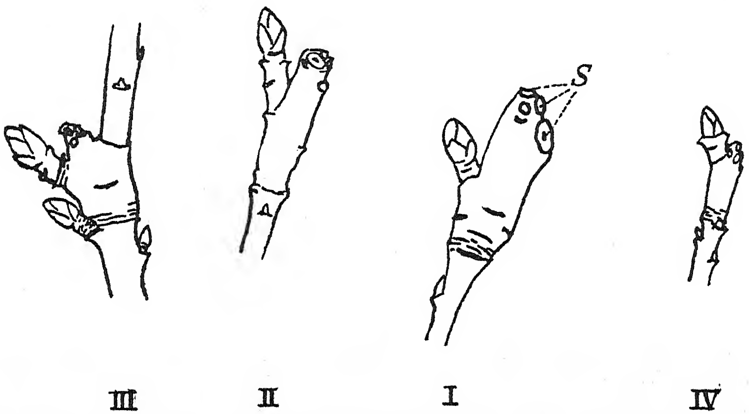


FIG. 30.—"Purses" ("cluster bases") from apple spurs. These club-shaped swellings mark blossoming (*cf.* Fig. 29). The more or less circular scars mark the spots where blossoms or fruits dropped off; their size gives some indication of the stage of development of the fruit when it was separated from the purse. An apple matured on (I), leaving the large scar; on (IV), fruit development stopped at the blossom stage. From the buds further growth proceeds (*cf.* Fig. 29).

fact that some of the young spurs do not bear in their second year, but come into production a year later, in unison with spurs with which they should alternate. A killing spring frost may destroy the blossoms; the spurs which should have borne this year are likely, under these conditions, to blossom again the next year in unison with the spurs which would normally bloom that year. The heavy crop thus induced is likely to result in absence of fruit-bud formation in any spurs for the next year, and the habit of alternate bearing is established unless it is broken up again by the spurs from new shoots. In some varieties alternate bearing

comes about in other ways, but it is nearly always the result of declining vigor.

Vigorous growth is rather closely connected with fruitfulness in the apple. Long shoot growth one year ensures a large number of lateral buds, making possible the formation of a large number of spurs in the next year; this in turn permits bearing of a large

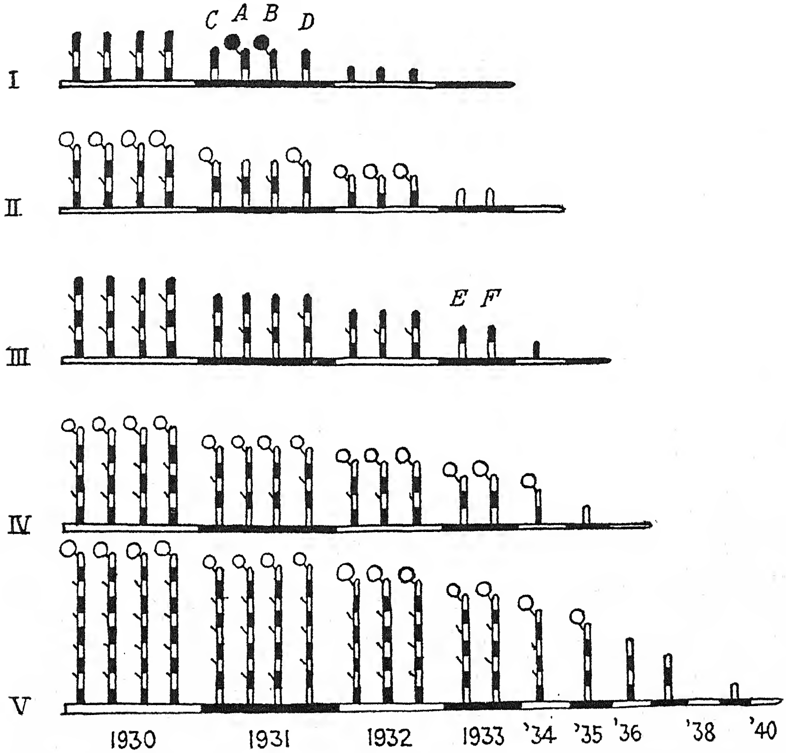


FIG. 31.—Diagrammatic representation of growth and fruitfulness in an apple tree in which growth is declining and a decline in fruitfulness is imminent. This might be conceived to be a continuation of the shoot shown in Fig. 28. Between (IV) and (V) three full seasons are supposed to have elapsed. Characters correspond with those used in Fig. 28. Note the transition to biennial bearing. See text for discussion.

number of apples in the following and in alternate succeeding years. Increased growth in any given year is not fully effective in increased production until the second year, but as long as the spurs formed on this increased growth continue to function the gain is maintained. Conversely, the older spurs may continue to function normally on a tree that is decreasing in vigor, but the

new spurs are less numerous and are likely to be slower in coming into bearing. A large apple tree may, then, "stand still" and yet be productive for a number of years, merely because of the great number of old spurs, even though no new spurs are formed. Sooner or later, however, the old fruiting wood becomes reduced from breakage and shading and ultimately it declines in productivity. Without new spurs to replace these losses, yield

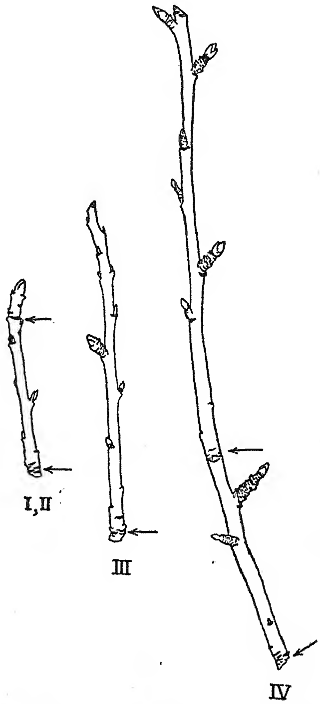


FIG. 32.—Five years' growth in a shoot on a non-vigorous apple tree. Contrast with Fig. 27. No blossoming in the 5 years. Arrows mark beginning of each season's growth.

declines (Fig. 32). Consequently the absence of moderately vigorous growth is a cautionary signal, even though the tree may be heavily loaded with apples.

Growth may be too vigorous for fruitfulness, in that lateral buds, which should produce spurs, actually produce shoots with lateral buds that produce more shoots, and so on. This is the condition in vigorous young trees, but excessive vigor is rarely a cause of unfruitfulness in mature trees.

The pear has a fruiting habit practically identical with that of the apple.

THE GROWING AND FRUITING HABIT OF THE PEACH

In the peach, the relation between growth and fruitfulness is even closer than it is in the apple, for the shoot growth of one

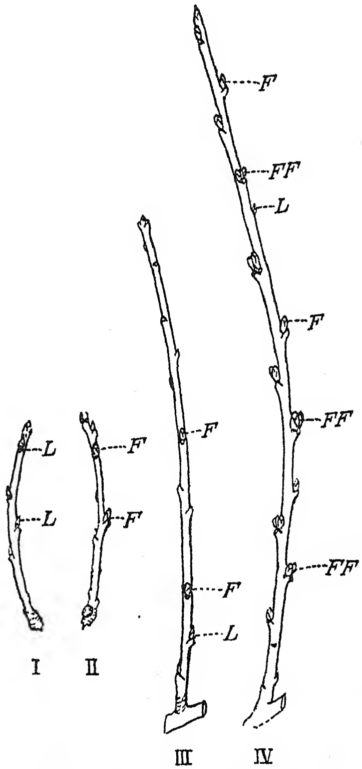


FIG. 33.—Shoots and spurs of one year's growth in a moderately vigorous peach tree. *F*, single fruit bud; *FF*, collateral buds, two fruit and one "leaf;" *L*, "leaf" buds. Collateral buds are much more common on rather vigorous shoots (*cf.* Fig. 35).

year contains the fruit buds for the next year. Examination in winter of a shoot about 1 or 1½ feet in length generally shows three types of buds (Fig. 33). In the upper end, single buds (one at a node, as in the apple) predominate; these are of two kinds, one small and pointed, the other somewhat larger, rather inclined to rotundity, and more pubescent (hairy). In

the lower two-thirds of the shoot many of the nodes have, instead of a single bud, three buds, arranged side by side. The two outer are larger, rounder, and generally more conspicuous; the central bud of the three is frequently very inconspicuous, small, and pointed. The larger, rounder buds, single or in pairs, are "fruit

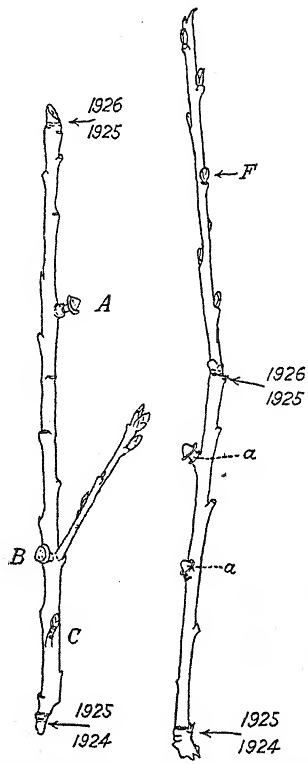


FIG. 34.—The character of a season's growth may affect its fruitfulness for several years. *A*, *a* represent "buttons" left when fruit was picked from single nodes; there is no provision for further fruitfulness at these nodes. At *B* was a collateral bud, as shown by the button and the spur growing beside it. The spur is bearing blossom buds. *C* shows a spur growing from a "leaf" bud. The twig at the right bears only on the new shoot growth.

buds;" the pointed smaller buds are leaf buds, containing a vegetative growing point.

The peach, then, differs from the apple, in forming fruit buds, so to speak, 1 or even 2 years earlier (Fig. 34). Many of the lateral buds which in the apple are destined to give rise to spurs, are in the peach destined to produce fruit. Consequently the

potential size of one year's peach crop is regulated by the growth the trees made in the previous year. The peach, therefore, responds more quickly to favorable or unfavorable growing conditions than the apple; on the other hand, it does not sustain its yield under cultural neglect as the apple does for some time.

The peach blossom-bud itself differs in character from the fruit bud of the apple. In the peach this bud contains ordinarily but one blossom and invariably no vegetative growing point, while in the apple one bud contains several embryonic flowers and at least one vegetative growing point. When a single peach

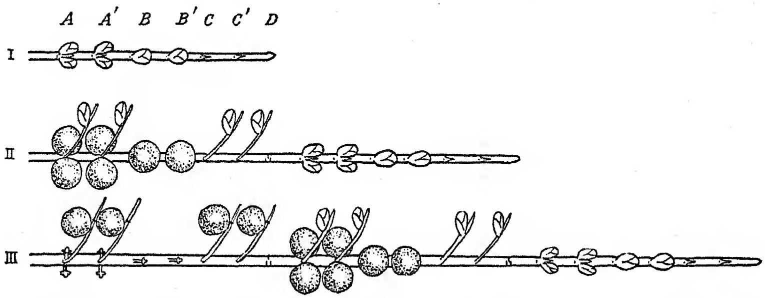


FIG. 35.—Diagram of fruiting habit of moderately vigorous peach tree. Three years' growth and performance of one shoot are represented. Nodes *A* and *A'* have collateral buds (*cf.* Fig. 34); *B* and *B'* represent single blossom buds; *C*, *C'* represent single leaf buds, and *D* the terminal. In the second year the blossom buds are bearing fruit, while the leaf buds have sent out lateral spurs, and from the terminal bud the shoot continues growth, forming fruit buds for the third year. This wood is still fruitful in the third year, though less so than in the second year. The spurs from nodes *A*, *A'*, *C*, *C'* may remain fruitful over a longer period than is here indicated.

bud opens its blossom a fruit may or may not develop at that point; in either case there is no provision for foliage or for continued growth at that node, unless there is also a separate and distinct leaf bud at that point, (Fig. 35), while in the apple the vegetative growing point provides for further growth and renewed fruiting on the same spur.

Because of this characteristic of the peach bud the nature of the growth made in any one year not only affects the next year's crop, but in some measure influences later productivity. Short growths, such as those made by a weak tree, are characterized by predominance of single fruit buds. When these have opened and perhaps borne, the portion of the stem which bore them is no longer capable of fruit production, except for a few short spurs growing out from leaf buds (Fig. 36). The bulk of the

crop, however, is borne near the tips of the branches, and yield cannot fail to be small; furthermore the fruiting area is continually moving outward, making the various cultural operations more difficult, while the easily accessible lower portions of the tree are unfruitful. Heavy heading in of these limbs by pruning, to bring them "within bounds," removes practically all the fruit buds.

On moderately vigorous shoots, the proportion of paired fruit buds is high. Though these individually do not differ from the single buds, the presence of a leaf bud at each node provides for

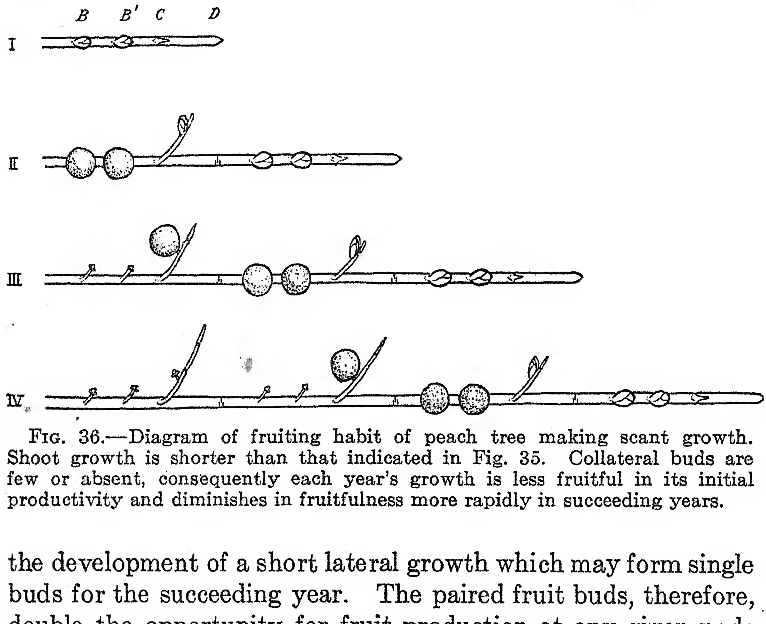


FIG. 36.—Diagram of fruiting habit of peach tree making scant growth. Shoot growth is shorter than that indicated in Fig. 35. Collateral buds are few or absent, consequently each year's growth is less fruitful in its initial productivity and diminishes in fruitfulness more rapidly in succeeding years.

the development of a short lateral growth which may form single buds for the succeeding year. The paired fruit buds, therefore, double the opportunity for fruit production at any given node and the leaf bud between them provides for subsequent fruitfulness on a short spur or shoot originating from that node (Fig. 35). Consistent, moderately vigorous growth, as compared with weak growth, provides more nodes, more fruit buds per node, and a longer period of fruitfulness for each node; there is, in short, a threefold increase in potential fruitfulness. Though the greater terminal growth extends the branches outward more rapidly, this tendency is partly offset by the wider distribution and greater number of fruit buds which permit rather heavy shortening-in without removal of the whole crop.

Extremely vigorous growth, however, reduces fruitfulness. A node which in the moderately vigorous shoot would form paired fruit buds with a leaf bud between them, sends forth, under very vigorous growth conditions, a side shoot called a "secondary"

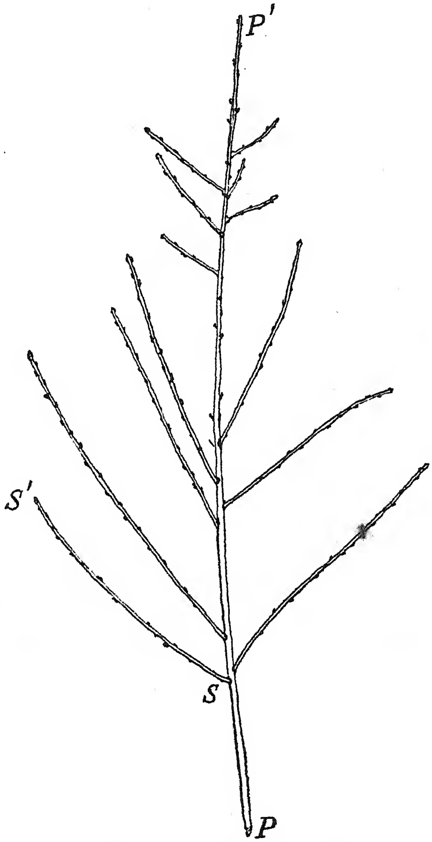


FIG. 37.—One year's growth in an excessively vigorous peach tree. Both the primary (*P P'*) and the secondary (*S S'*, etc.) shoots grew in the same season; primary shoot 46 inches long. Practically all the buds are leaf buds. This type of growth is perhaps less fruitful in the North than corresponding growths in the South.

(Fig. 37), because it develops in the same year as the main shoot. This supplants the leaf bud of the moderately vigorous type while the two outside buds fail to form blossoms and develop as leaf buds. On the secondary shoots a few scattering fruit buds may develop, but these are much less numerous than they

are in primary growths of equal length (Fig. 38) and the total of fruit buds on all the secondaries of a large shoot is frequently smaller than it is in a primary shoot equal in length to one of the secondaries. This type of growth is desirable in a very young tree where fruitfulness is not sought, because it results in early formation of a large framework on which somewhat less vigorous shoots can develop fruit, but in a tree of bearing age it is inimical to fruitfulness. Very heavy pruning leads to this type of growth and this type of growth frequently leads to further heavy pruning, establishing a cycle of unfruitfulness.

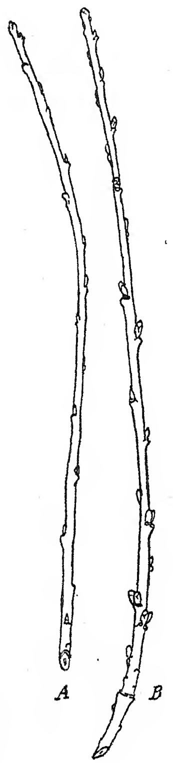


Fig. 38.—*A*, one of the secondary shoots from the excessively vigorous shoot shown in Fig. 37; *B*, a primary shoot of almost identical length from a tree making moderately vigorous growth. At least thirteen distinct fruit buds on *B* and only one doubtful fruit bud on *A*.

The fruiting habits of the apple and peach are not duplicated in the orchard in the rather simplified form presented here. Differences due to varietal peculiarities, and cultural and climatic variations may tend to make them seem superficially complicated. Basically, however, they are comparatively simple.

GENERAL CONSIDERATIONS

The two fruits that have been selected to illustrate bearing habits are simply types. Other fruit plants possess different characteristics. For example, the loquat, like the peach, bears fruit buds that contain flower parts only, but, unlike the peach, it bears these buds terminally. The grape, like the apple, bears mixed flower buds, but they are lateral instead of terminal and they give rise to long instead of short leafy growths. A number of other combinations or habits occur. In one sense these bearing habits are fixed characteristics of the variety or species and as such they are beyond the influence of any pruning or cultural practices. No treatment will make a cherry tree bear mixed flower buds or terminal flower buds. If it bears at all, its flowers will be lateral and the individual flower buds will give rise to inflorescences only, not to any vegetative growth. On the other hand, bearing habit, in the sense of refer-

ring to amount and type of vegetative growth, relative abundance of flowers, regularity of their production, and the setting and maturing of fruit, is materially influenced by pruning and cultural treatments. Through a careful study and comparison of the bearing habits of his trees, the orchardist can learn to read the record of their performance, to diagnose their condition, to forecast their functioning, and to deduce their requirements.

CHAPTER VII

THE TREE'S CARBOHYDRATE SUPPLY

Fruit production is primarily carbohydrate production. If the fruit plant cannot manufacture carbohydrate in adequate amounts, its fruit cannot ripen and its wood cannot mature properly. Except for this, peaches could probably be grown in Iceland, where the winters are not as cold as in the peach-growing areas of New York and Connecticut but where the summers are too cool and the growing season too short for the production of the carbohydrate required to ripen the fruit and to mature the wood. The extraordinary growth sometimes made by young trees whose tops are "inarched" (grafted) into older trees—a growth sometimes larger than any secured in free-growing trees by fertilization with nitrogen—indicates that small trees can utilize more carbohydrate than they can manufacture and that carbohydrate supply may limit growth to an extent rarely suspected. In many countries the northern limit of grape growing is fixed by the amount of carbohydrate the plant is able to make during a season. This is true especially for the culture of the European grape, which is grown chiefly for wine making. When the summers are not warm or the autumns mild the grapes do not become thoroughly ripe and their sugar content is too low for good wine. Weather conditions that favor carbohydrate manufacture affect the quality of prized vintages, particularly in the more northerly grape-growing regions, so that wines of one year may command higher prices than those of another year, though produced in the same vineyard.

In addition to being essential for the development and ripening of a crop of fruit, carbohydrate is one of its main constituents. In a bushel of apples weighing 50 pounds, water averages over 42 pounds, carbohydrate 7 pounds, and all other constituents less than 1 pound. Nine-tenths of the residue left after the removal of all the moisture from common fruits is carbohydrate; so also is 70 to 85 per cent of the dry weight of the wood in the tree from which the fruit is harvested. The growing of the fruit

tree is nearly as much a matter of carbohydrate production as is the bearing of a fruit crop.

Carbohydrate production is the prime function of every green leaf and perhaps the most important of all plant functions. Though many kinds of carbohydrate are found in plants, they are all derived directly or indirectly from one. This is a sugar; it is not the kind generally called to mind when the word is mentioned, namely, cane sugar, which is obtained from the sugar cane and the sugar beet, but one first found in grapes and therefore called grape sugar. Plants contain several kinds of sugars and mixtures of these are found in every portion of the plant, but nowhere in greater abundance than in the juices of some fruits.

How Carbohydrates Are Made.—Though it is one of the simplest of all carbohydrates, grape sugar is itself a complex chemical compound. Plants make it, however, from very simple and common substances, namely water and carbon dioxide. The latter is a gas absorbed by the leaves from the air, in which it is always present in small but remarkably constant amounts; it is the substance that gives the pleasant tingle to carbonated drinks and forms the active principle of nearly all chemical fire extinguishers.

Water and carbon dioxide, then, are the ingredients from which sugar is made. The process of manufacture takes place, however, only in the presence of light, for the energy necessary for sugar synthesis comes from sunlight. Carbohydrates, like other foods, contain energy; they may in fact be regarded as a kind of fuel which can release its stored energy, sometimes in a very spectacular manner. In a sense, the energy of light may be considered one of the ingredients that unites with carbon dioxide and water to form sugar, and carbohydrate may be considered a sort of storage battery for the energy of sunlight.

The manufacture of sugar, like many other processes of manufacture, requires certain machinery. One essential part of the machinery used by the plant in making sugar is its green coloring matter, which is concerned in some way with the transformation of the radiant energy of sunlight into the chemical energy of carbohydrates. The direct products of sugar manufacture in plants are grape sugar and oxygen. The latter is given off from the plant as a gas and passes out into the surrounding air through the stomata as carbon dioxide passes in.

The manufacture of sugar from carbon dioxide and water takes place almost exclusively in the leaves. These organs are particularly suited for this work because of the large surface they expose to the sun and air and their equipment of green pigments. The leaves, then, are the source of supply for the whole plant, since other parts of the plant, such as the roots, are unable to make sugar. In fact, the entire organic world depends on the leaves of plants for carbohydrate, since animals must either live directly on plant products or on other animals that in their turn subsist on them.

Most of the grape sugar made in the leaves during the day passes out at night into the twigs and is carried to all parts of the plant, through the inner layers of the bark. There it is used in many different ways. It may be transformed into some other kind of sugar, such as fruit sugar or cane sugar. It may condense to form more complicated types of carbohydrate. Wherever sugar accumulates, it tends to change into starch, the form in which carbohydrate is stored in nearly all plants. Starch is readily converted to grape sugar and grape sugar is changed just as easily to starch. During the daytime when grape sugar is being manufactured in the leaves, it is often transformed immediately to starch. This change is so rapid that for a long time starch, rather than grape sugar, was thought to be the first carbohydrate formed in the leaf. At night the starch is changed back again to sugar which passes out of the leaf into the plant where it may be converted into starch a second time. Some of the sugar travels through the phloem all the way down to the roots before it is stored away in the cortical tissue as starch; some is sidetracked along the way in the trunk and main scaffold limbs and accumulates as starch in the medullary rays of wood and bark; some stays in the shoot at the base of the leaf that made it and is stored in the pith, rays and bark. As a bud usually develops at the base of each leaf, this starch constitutes an initial supply which the bud can use when it opens the following spring.

Starch begins to accumulate in roots and branches as active vegetative growth slackens. This occurs generally early in the summer and accumulation goes on as long as the leaves are active; the maximum amount is usually found sometime in September, and thereafter it decreases. During the winter the amount of starch becomes very much reduced, for in very cold weather it is

converted back to sugar. As spring approaches the starch reappears in considerable quantities before growth commences, and during spring growth practically all the starch is converted to sugar again.

At this time a part of the sugar is used in tissue building, to build cell walls, for example. Chemically the walls of plant cells consist for the most part of cellulose. This is simply another form of carbohydrate that, like starch, can be broken down to grape sugar, though by no means so easily. Cellulose is not a form in which carbohydrate is usually stored; it is a permanent part of the plant's structure.

Sugars are not only used to build up more complex carbohydrates, but they are also broken down to simpler compounds that are not carbohydrates. They may give rise to those acids that affect the flavor of fruit, such as malic acid, the chief acid of apples, and tartaric acid, the chief acid of grapes. The production of acetic acid from sugar by fermentation is of great interest to the apple grower. Although acetic acid may be produced directly by sugar fermentation, higher yields are obtained by first fermenting the sugar to alcohol with yeast and then oxidizing this to acetic acid with the aid of the proper bacteria. The best apple vinegar is made in this way.

Besides organic acids, sugars are the starting point in the formation of many other substances. They may be used in the formation of proteins and of many pigments and there are strong indications that they may also be converted into fats and oils. Of the 10 per cent of the dry weight of the fruit and of the 15 or 30 per cent of the dry weight of the fruit tree that is not carbohydrate, by far the major part consists of compounds that are built up more or less directly from it.

Carbohydrates as a Source of Energy.—The greatest value of sugars does not consist so much in the products into which they may be built up or broken down, but rather in the energy released during their complete decomposition to carbon dioxide and water, the substances from which they were originally made. The energy of sunlight, entering into the composition of sugar during its manufacture, is released again when the sugar is oxidized and the energy thus liberated is used by the plant not only in its growth processes but for its other vital activities. Indeed, carbohydrates are fuel, carrying the energy of sunlight to all portions of the plant. It is well known that guncotton, which is

nitrated cellulose, is an explosive; finely divided sugar floating in the air of a closed room, has ignited with destructive violence.

The task of every living organism, whether plant or animal, is to release the energy of the carbohydrate fuel not with the suddenness of an explosion but steadily and gently, in such a way that it will be available for vital activity. The process by which this is done is respiration.

When the plant is inactive, respiration may be slow and the amount of carbohydrate consumed to release energy may be small, for respiration is regulated according to activity. Germinating seeds and bursting buds, however, respire at a rate comparable to that of warm-blooded animals, and consume carbohydrates just as rapidly in proportion to their weight. During the course of a year the amounts of carbohydrate used in this way by a fruit tree are very considerable. Probably 9 out of every 10 pounds of carbohydrate produced are burned up again to supply energy and only 1 pound remains to be built into the permanent framework of the plant or into the tissue of the fruit that is harvested.

The importance of carbohydrate to the fruit tree is most evident when the supply is inadequate. If the tree is bearing a crop, the first symptoms of a deficiency appear in the fruit. The size, color, and flavor of most fruits depend directly on carbohydrate. Small, poorly colored, sour, or tasteless fruit is often an indication of a carbohydrate supply insufficient to meet the requirements of the developing crop. One remedy is to thin the crop, so that each fruit will have enough carbohydrate to attain full size. The full color of some fruits, such as the apple and peach, develops only when they are exposed directly to sunlight; shading by dense foliage generally prevents full coloring. Grapes and cherries, however, color just as well in the shade as when exposed to the light, and the removal of leaves to let the light in does not improve the color but tends rather to prevent coloring by reducing the carbohydrate supply necessary for its full development.

Carbohydrate deficiency is by no means a rare occurrence, even aside from that imposed by the character of the growing season. Production of an excessively large crop seems to deplete the carbohydrate supply in the branches below normal, and renders the tree particularly liable to injury from cold weather. A heavy fruit crop noticeably reduces vegetative growth and thus, in

many plants, diminishes the potential size of future crops. Temporary deficiency resulting from crop production seems also to tend toward inhibition of fruit-bud differentiation in apple spurs. Defoliation by fungi or insects, even when a second set of leaves is produced, generally reduces the carbohydrate supply sufficiently to give the tree an extra "off" year. The diminution of root growth following heavy pruning of the top must be attributed to carbohydrate deficiency.

Other processes important in horticultural practices may be inhibited by a low carbohydrate supply. Plant propagators carefully avoid particularly soft tissues when they are making cuttings, since the scantiness of the carbohydrate supply diminishes root formation. Callus growth also depends on carbohydrate. A girdled tree trunk forms more callus along the upper edge which is receiving a constant supply of carbohydrate from the top than along the lower edge which is cut off from the main supply. The union of grafts, the healing over of pruning wounds and all similar processes depend on a plentiful supply of carbohydrate, and fail to take place if it be low. Failure of callus formation on stubs left in pruning is due to failure of the carbohydrate supply at these points. Of course, growth in general requires carbohydrate, but when the supply is limited, fruit and root development are usually affected before other growth processes.

Normal fruit plants seldom accumulate carbohydrate in excessive amounts, except possibly very old trees or biennially bearing varieties during their off year. An excess of carbohydrate affects the plant very much as does a dearth of nitrogen. In fact, the two conditions are likely to occur together. Shoot and leaf growths are retarded, the leaves turn pale green or yellow and eventually fall off. In general, carbohydrate and nitrogen have diametrically opposite effects on the plant.

CONTROLLING THE CARBOHYDRATE SUPPLY

Some of the factors influencing carbohydrate supply are not subject to control. Temperature and moisture are generally the most important. Within limits, the warmer it is and the more moisture it can command, the more rapidly a plant grows and the greater are the amounts of carbohydrate used in supplying energy and in building new tissue. The conditions of temperature and moisture that favor growth also promote

carbohydrate manufacture, for this process, likewise, goes on more rapidly at higher temperatures, and water is one of the ingredients out of which carbohydrates are made.

A temperature may prevail, however, where carbohydrate consumption by respiration proceeds more rapidly than its production, since respiration goes on all the time and carbohydrate manufacture occurs only in the presence of light. Some such condition probably sets the southern limit of culture for many fruits, the apple being a striking case in point.

Temperature is not within control and direct control of moisture is practiced only in irrigated sections. The only practical procedures are indirect. Carbohydrate consumption may be reduced and the available supply made more effective by thinning the fruit. The supply may also be restricted to certain parts of the tree by girdling. This a rather extreme treatment attended by considerable danger, but on trees destined to bear but a few crops, as is the case with "filler" trees, it has been successful. A safer method that has a marked, though likewise indirect, effect on the available carbohydrate supply and involves little difficulty or expense, is to manipulate the nitrogen supply. Nitrogen promotes vegetative development and thereby reduces the supply of available carbohydrate by increasing its consumption. The vegetative growth which nitrogen tends to induce, however, leads to the development of a larger shoot and leaf system and hence to a larger carbohydrate-producing mechanism. In this indirect way, nitrogen applications not infrequently produce an ultimate increase in the available carbohydrate supply of the plant. Judicious use of nitrogen-carrying fertilizers permits, then, either increasing or decreasing the available carbohydrate supply in the fruit tree. Which effect predominates depends on the amount applied and on the time of application.

CHAPTER VIII

FRUITFULNESS

In the days when England was Merrie England the rural New Year's Eve observance included the wassailing of the apple trees. Troops of men and boys visited the orchards and encircled the trees, repeating incantations of this sort:

> Stand fast root, bear well top,
> Pray God send us a good howling crop;
> Every twig, apples big,
> Every bough, apples enow,
> Hats full, caps full,
> Full quarter sacks full.

The stanza was chanted to the accompaniment of music on a cow's horn and ended in a loud shout; during the ceremony the trees were rapped with sticks. The next crop being thus assured, the celebrants visited the manor house to claim their reward in food and drink.

Other people and other generations have concerned themselves in various ways to insure crops on their fruit trees. Sacrifices, incantations, libations, terebrations, and prayer have been used at one time or another. More sophisticated times, however, have been disposed to seek other methods, more prosaic perhaps, but likewise more rational. Incantations on New Year's Eve are now known to be 5 or 6 months late, because the formation of blossom buds, which is obviously a necessary antecedent to a crop, occurs—or fails to occur—in the summer preceding blossoming. This knowledge, however, was not gained at once. As fruit crops have assumed increasing importance among the items of farm revenue, increasingly close scrutiny has been given the trees that bear them, and since easy transportation has enabled men to leave their own orchards and see fruit trees growing under various conditions and to talk with other orchardists, a fund of lore has developed concerning the association of environment and treatment with fruitfulness.

Numerous generalizations have grown out of all this accumulation of experience and observation; many of these concern the things which make trees blossom or fail to blossom. These generalizations, though they may touch upon various details, have a notable tendency to point in one general direction. They indicate more or less antagonism between vigor and fruitfulness. Trees in a dying condition are said to be particularly full of bloom. Limbs of trees that have been girdled, it is claimed, exhibit the same phenomenon. Trees are sometimes grafted on certain kinds of roots, which diminish the vigor of their growth, producing dwarf trees that bear earlier than those growing on the more vigorous "standard" roots. Trees grown in sod or in poor soil are said to bear earlier than those grown under high cultivation or in rich soil. Cutting of the roots is supposed to check growth and make trees fruitful. In all these cases the less vigorous trees appear to blossom at an earlier age or more abundantly than the more vigorous trees. If these assertions are correct, the practices prevailing among the best fruit growers and in the best fruit regions—practices which in the main promote vigor—seem curiously inconsistent, if not absolutely erroneous, and studious neglect would appear the better treatment. If the practices are correct, the generalizations would appear to be without foundation. Strangely enough, experience has demonstrated that the practices are, in the main, correct and also that the generalizations are, in the main, well founded. There must be, then, some consistency in this inconsistency.

Despite the implication conveyed by its association with practices such as girdling, root pruning, and dwarfing, blossoming is not an unnatural process. Every tree growing in the forest is the result of blossoming of some parent tree. The sturdy "cabbage" pine, growing in an abandoned pasture, surrounded by a numerous progeny of young pines, is evidence that maturing of seed is not fatal to the parent tree. The difference in this respect between forest trees and cultivated fruit trees is quantitative. The pine blossoms perhaps one year in six; the orchardist wants his trees to bear annually. Generations of selection of varieties, in which scant bearing has been one of the reasons for elimination and heavy bearing one of the reasons for preference, has undoubtedly produced a race of fruit plants with a propensity for blossoming early and freely. Indeed, with many fruit plants, such as the raspberry (Fig. 40), the blackberry, the grape, and the

peach, blossoms are formed annually beyond the power of the plant to mature the resulting fruits, and large or at least better crops are secured by helping the plant to develop a limited number of fruits rather than by increasing the number of blossoms. The apple, however, with its tendency to bear only in alternate years, is frequently limited in productivity by scarcity of blossoms and the factors concerned with their abundant formation become the object of a very practical interest.

FRUIT-BUD FORMATION

Under some circumstances, the removal of a ring of bark from a limb of an apple tree is followed by abundant blossoming in the portions above the girdle, even though the rest of the tree has no blossoms whatever (Fig. 39). Buds of types which rarely blossom in normal trees will, under these conditions, develop flowers. In the apple, then, any bud is potentially a blossom bud (or "fruit" bud).

Girdling done at various seasons is not, however, equally effective. Done in the spring, no matter how early, it is not followed by blossoming during the same year, and practised in August it has no effect on blossoming in the following spring. It is effective only when done before the first of July and then, of course, only on the bloom of the next year. Apparently then, though any bud is potentially a blossom bud, it can become one only at certain periods.

The first indication of blossom-bud formation in the apple is visible with the aid of the microscope about the first of July. Previous to that time all the buds appear substantially alike, except possibly for a somewhat tighter packing of tissues in those that are destined to become blossom buds. In general, however, all buds appear to be leaf buds up to the time of differentiation, which may be considered to be prevailingly the last of June.

The date of this differentiation assumes significance when it is related to the growth of the tree and to the chemical changes that take place as the season advances. The spurs, which bear the bulk of the crop and form blossom buds earlier in the season than the shoots, make their whole length growth within a few days after the buds open. In a week after the blossoms fall, the length growth of the spurs is complete; thenceforth the visible change is in diameter only. Coincident with this early rapid

growth, the carbohydrate content of the spurs falls to a very low point, these materials having been consumed in the manufacture of the new growth as well as in the laying down of new rings of wood around last year's wood in older growth. With the length increase finished, the consumption of carbohydrates diminishes and the leaves begin the accumulation of a new store of these

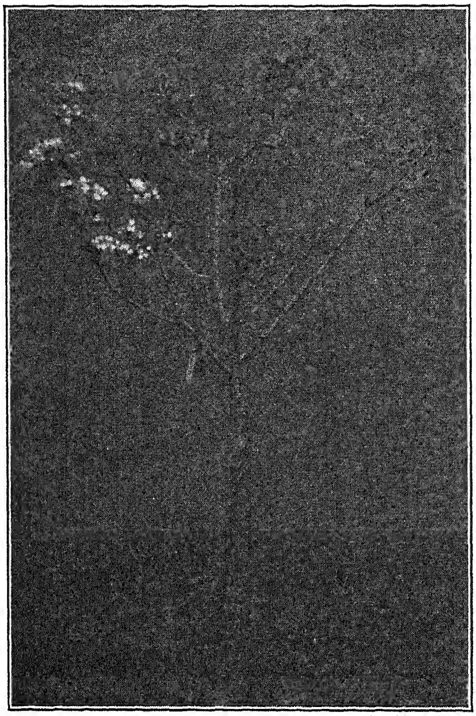


Fig. 39.—One branch of this tree has been girdled by the wire label. The resulting accumulation of carbohydrates above the constriction has led this branch to begin bearing earlier than the rest of the tree.

materials. By the end of June the carbohydrate store has reached a high point and differentiation of blossoms occurs within the buds which continue to develop until advancement is checked by cold weather; with the return of warm weather in the spring the development of the blossoms proceeds rapidly (Fig. 16), the buds open, the blossoms unfold, and are soon ready for setting the fruit crop.

Whether or no the accumulation of carbohydrates in the new wood of the spurs actually causes the differentiation of blossom buds, they at least present a striking parallel. The conditions which lead to carbohydrate accumulation are likely to lead also to the formation of blossom buds. Girdling, dwarfing, root pruning, growth in poor soil or in sod, all check the consumption of carbohydrates and favor their accumulation; they also tend to induce the formation of blossom buds. Conversely, particularly vigorous growth, which involves consumption of carbohydrates, or heavy shading, which reduces their manufacture, are alike characterized by absence of blossom bud formation.

RELATION OF VIGOR TO FRUITFULNESS

There appears to be plenty of evidence that lack of vigor favors fruitfulness and, by inference, that poor soil is the best location and that abuse, or at least neglect, is the best treatment for fruit trees. This inference seems not easily reconciled with the fertilization and cultivation given fruit trees in many successful orchards, where no little labor and expense are incurred to avoid neglect. The clash of evidence, however, is more apparent than real, and much of the difficulty disappears when the terms are more closely defined. Vigor and lack of vigor are relative terms, and each has degrees of comparison; growth may be moderately vigorous or luxuriantly vigorous; it may be slightly lacking in vigor or extremely lacking in vigor.

The more careful discrimination involved in the distinction between extreme conditions and moderate conditions qualifies the generalizations as to the connection between abundant blossoming and lack of vigor. Girdling is most effective on trees that are at least moderately vigorous; it has little effect on dwarf trees or on trees that have consistently made but little growth. Root pruning, as practised by its foremost exponents, was accompanied by fertilization. The dying tree loads itself with blossoms only when death is coming upon it comparatively quickly, after a period of at least fairly vigorous growth; the last stages of prolonged starvation are characterized by absence of blossoming. If the growth of a vigorous tree is arrested, the tree becomes fruitful, but if the extreme lack of vigor persists, blossoming ceases. In short, blossoming accompanies a check in growth, a change from a vigorous to a non-vigorous condition, rather than a consistently weak condition.

In all of these cases the carbohydrate content of the tissues is high. Mere accumulation of these materials, therefore, is not sufficient to induce copious blossoming. Possibly, among the many substances grouped as carbohydrates, some one compound which is essential to the process is reduced in amount or absent altogether in these extremely weak-growing trees. However, greater plausibility attaches to the conception that a moderate amount of nitrogen also is essential to the formation of blossom buds. This accords with the abundant blossoming of trees whose vigorous growth is arrested, where presumably a nitrogen residue persists for a time, and also with the absence of blossoming in trees which consistently lack vigor, where the nitrogen supply is extremely low, and blossom-bud formation may be induced by moderate applications of nitrogen.

The somewhat accidental or artificial cases of growth checking, resulting in fruitfulness, which have been enumerated are duplicated on a far greater scale under normal cultural conditions in the orchard, when, after the first flush of growth, length increase ceases in most parts of the tree. A tree may be vigorous, as measured in terms of total annual growth, and at the same time its vigor may change during the growing season; it may be vigorous in the spring and later lack vigor, insofar as this is measured by length growth. This is the condition under which fruit buds are formed. Vigorous growth early in the season, then, need not preclude the differentiation of blossom buds later and moderate early spring applications of quickly available nitrogen-carrying fertilizers are not antagonistic to this process, when they do not persist in the soil and prolong growth late in the season. A fair amount of independence in action between various parts of the tree makes it possible for the spurs of an apple tree to cease growth and form fruit buds, while the shoots at the tips of the branches are still elongating; these may stop growth later and have an independent period of blossom differentiation in either terminal or lateral buds.

TREE FRUITFULNESS AND ORCHARD YIELDS

Crop production and orchard profits are not wholly tied to the earliest and the highest percentage of blossom bud formation; "abundance" of blossoms should signify not only a high percentage but also a large number. The dwarf tree may bear

early, but its crop is small and increases little from year to year; when the standard tree does bear, its greater size enables it to outyield the dwarf tree, even though its percentage of blossom bud formation (that is, the average percentage of spurs blossoming or the average number of buds to each spur or shoot) may be lower. Consequently, fertilizing of young apple trees during their first few years in the orchard, when they do not bear under normal conditions, utilizes an opportunity to make a larger tree with little or no sacrifice in fruitfulness. As the tree approaches the bearing age of the variety, fertilization should be diminished or stopped.

Later in the life of the tree this quantitative aspect of fruit-bud formation may again assume importance. Heavy crop production tends to slacken growth; this slowing down may be furthered by other influences and at, perhaps, 25 to 30 years, the tree may be making little new growth, though the spurs continue to function. If this condition persists the number of fruit spurs may actually diminish, through breakage, crowding and starving, and the yield may decrease, even though the percentage of blossom-bud formation has not diminished. Consequently, growth stimulation one year may result in a subsequent crop increase through the formation of new spurs.

Fruitfulness, then, is a twofold problem; it is concerned not only with percentages but also with total numbers of blossom buds. Nitrogen, through its effect on growth, directly affects the number of places where blossom buds are likely to form in trees bearing fruit buds on their shoots, and it has the same ultimate influence in those fruits like the apple that bear on spurs; the actual differentiation depends on a balance between nitrogen and carbohydrates. Under normal conditions the requirement of nitrogen for shoot growth is apparently greater than that for blossom-bud formation; certainly lack of nitrogen is reflected in deficient shoot growth before it becomes effective in reducing blossom-bud differentiation and nitrogen supplies sufficient to induce reasonably vigorous shoot growth do not bring an excess into the spurs. Under the same conditions blossom-bud differentiation is affected more often by the carbohydrate than by the nitrogen content. Spurs which are forming blossom buds and those which are not forming them vary little or none in their nitrogen supplies, but those which are to form blossom buds have the higher carbohydrate content.

In general it may be said that the ideal state of vigor in trees or bushes that bear on spurs is realized when a maximum amount of shoot growth is being produced without at the same time having many spurs grow out into shoots; in trees or shrubs that bear on shoots usually the greater amount of this shoot growth the better, for the total number of blossom buds is thereby increased. In brief: shoot length alone in the shoot bearers and shoot length and spur number in the spur bearers are the yardsticks by means of which any grower can measure the efficiency of his soil management methods, for they are the yardsticks that measure present and future production possibilities.

CONTROLLING GROWTH AND FRUITFULNESS THROUGH THE NITROGEN SUPPLY

In the orchard the fruit grower, consciously or not, is manipulating nitrogen and carbohydrate, in an effort to secure fruit

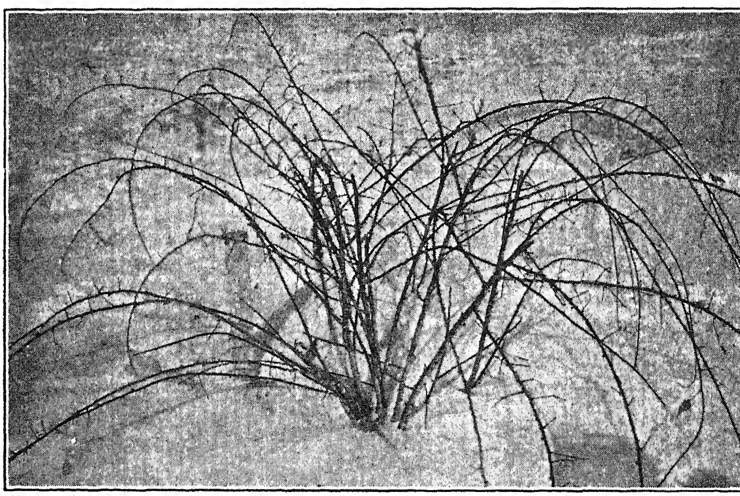


FIG. 40.—A typical, vigorous black raspberry hill. Its ten canes carry 1,750 live potential fruit buds. Fruit-bud differentiation is never a limiting factor in the culture of this fruit. Material reduction in number of fruit buds by means of pruning is necessary.

crops. Nitrogen can be fed to the trees; carbohydrate cannot be fed to the trees but must be manufactured by them. Of the two, nitrogen is far more easily varied. It is increased absolutely by fertilizer applications or by cultivation and rela-

tively in some measure by pruning; if necessary it may be decreased by close cropping of the soil with a grass or grain crop. Control of the carbohydrate supply depends, primarily, on manipulation of the nitrogen supply, and, secondarily, on protection of the foliage from insect pests and fungus diseases, and to some extent on special types of pruning.

If the passage of two centuries and a change in the scene of effort have brought any fundamental change in cultural practices for fruit trees, it consists in some shifting of the effort at manipulation. The choicest dessert fruit of the seventeenth century in Europe was produced in small orchards, where spading and manuring kept the nitrogen supply always rather high, and much of the labor of pruning and of the care and thought involved in locating and training trees was devoted to unconscious efforts at manipulating the carbohydrate supply. In the more extensive American orchard of the present, carbohydrate is less frequently a limiting factor and cultural effort has, in the main, been more successful through manipulating the nitrogen supply. However, what John Lawrence wrote in 1717 still has rather general applicability:

> . . . the want of plenty of Blossoms in any Fruit Tree, is (generally speaking) a Reproach to the Skill of the Gardener. For tho' he cannot command Fruit from Blossoms, on the account of bad and unkind Seasons, and so cannot have it *when* he pleases, yet he may in a measure have it *where* he pleaseth, and keep almost all parts of the tree in a bearing state.

In general, it is probable that production is limited more by failure to get fruit from blossoms than it is by lack of blossoms.

CHAPTER IX

GETTING FRUIT FROM BLOSSOMS

Abundance of blossoms does not necessarily insure a crop at harvest. A tree or an orchard may blossom profusely and still fail to form or "set" fruit. Sometimes this failure is due to adverse external conditions which are generally obvious, such as frost or heavy rains; in other cases the cause is obscure.

In the early years of the past century, those engaged in the new industry of commercial strawberry culture were frequently confronted with cases of apparent stubbornness in their strawberry plants. Varieties which looked promising and yielded heavy crops in the trial grounds would become almost barren when planted in large blocks for commercial production. They still blossomed freely but they bore next to nothing.

Some time between 1820 and 1830, the farmers supplying the markets of a thriving Ohio village called Cincinnati began to wonder at the success attained in strawberry culture by a newcomer from Philadelphia, an "unlettered market gardener," named Abergust. Said Nicholas Longworth, one of the ablest horticulturists America has produced, and a neighbor of Abergust, "While I could from one-fourth of an acre, scarcely raise a bushel, he would raise 40 bushels." For many seasons Abergust supplied nine-tenths of the strawberries sold in Cincinnati. In Philadelphia his success had been as striking and as mysterious, for he steadfastly refused to divulge the secret of his yields. Plants discarded by him and thrown into the road were eagerly transplanted to other fields, where they "never bore a single fruit." Abergust continued to dominate the Cincinnati markets, since he raised, not only vastly more, but also larger berries, for which he received 25 to 37½ cents per quart, a very fine price in those days. From his sales he amassed a competence.

One day, however, Abergust's son showed what happens to idle hands. Instead of weeding strawberries he wandered over into Mr. Longworth's strawberry bed, where he "let the cat out of the bag." He observed that the crop would be poor. Mr.

Longworth said that it always was poor, whereupon young Abergust told him that the plants were all of one sex. He then became reticent, but Longworth had secured a hint sufficient to enable him to realize that his refractory varieties bore imperfect blossoms. Being without anthers, which produce pollen, these pistillate or imperfect blossoms could bear fruit only as chance brought to the stigmas pollen produced by plants of other varieties which had anthers and pollen (Fig. 41). This explained why a variety,

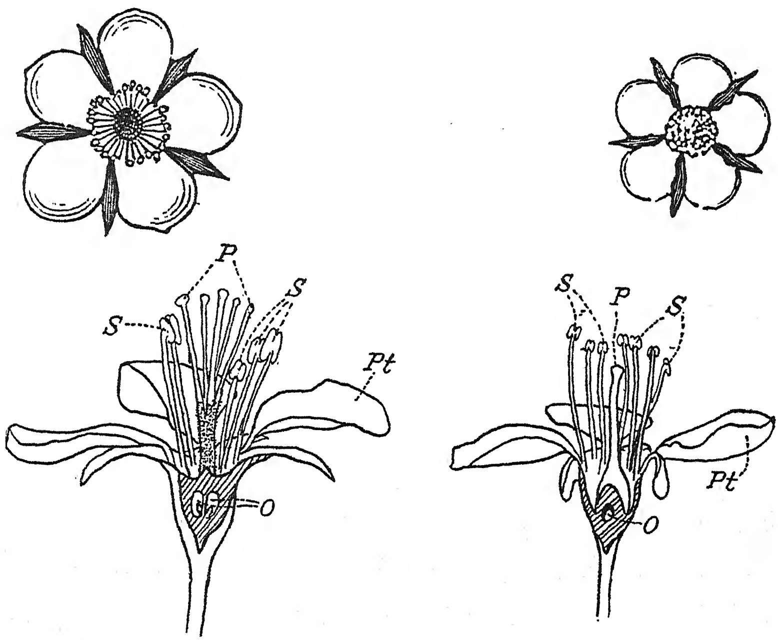


FIG. 41.—Upper row, strawberry blossoms; left, perfect; right, pistillate. (*From Longworth.*) Lower row; left, apple blossom; right, cherry blossom. *Pt*, petals; *S*, stamens, with anthers; *P*, pistils (five in apple, one in cherry); *O*, ovaries, with young ovules ("seeds"). The number of stamens shown is considerably less than the blossoms contain.

planted in trial grounds in close proximity to other varieties, bore abundantly, while planted in large blocks, with no plants of another variety near, the same variety became barren. It indicated that Abergust had thoughtfully discarded only one type of plant, to mystify his neighbors.

Instead of clinging to this secret, as Abergust had, and capitalizing it to his own profit, Longworth went to no little pains to broadcast his information. He did more. When others were

reluctant to accept his view, he tried to convince them. Then followed the controversy known as the "Strawberry War." While this was dragging through pages and years, the market gardeners of Cincinnati were planting pollen-producing varieties among their pistillate plants and turning into the Cincinnati market on a busy day as many strawberries as the Boston market received in a season. The crops increased so much more rapidly than the market expanded that for a time prices fell to 3 or 4 cents per quart and Abergust quit strawberry growing and engaged in raising vegetables.

Gradually strawberry production became organized on a basis of adjustment to the new knowledge of the necessity of cross-pollination for the pistillate varieties. In practice this means that no more than three, or possibly four, rows of pistillate plants should be set without an accompanying row of a perfect-flowering variety. As a guide to the grower the strawberry catalogue distinguishes between pistillate and perfect flowering, the pistillate being generally designated by a symbol, such as "P" for pistillate, or "I" for imperfect, while perfect flowering is denoted variously by such terms as "per." for perfect, "her." for hermaphrodite, "S" for staminate. Unfortunately some catalogues use the symbol "P" for perfect flowering.

The rapid succession of new strawberry varieties has provided the grower with such abundance of satisfactory perfect-flowering varieties that the pistillates are far less important than they were in an earlier generation and there is, in most cases, little reason for growing them.

EARLIER KNOWLEDGE OF CROSS-POLLINATION

It is interesting to note that Abergust was not the first discoverer of the imperfect flowering condition in strawberries, for Michael Keens, practical gardener in England, wrote in a letter dated July 9, 1817:

> I learned the necessity of mixing the male plants with the others, by experience, in 1809; I had, before that period, selected female plants only, for my beds, and was entirely disappointed in my hopes of a crop. In that year, suspecting my error, I obtained some male blossoms, which I placed in a bottle on the bed of female Hautboys. In a few days, I perceived the fruit near the bottle to swell; on this observation, I procured more male blossoms, and in like manner placed them in bottles,

in different parts of the beds, removing the bottles to fresh places every morning, and by this means obtained a moderate crop, where I had gathered no fruit the preceding year.

Though this was read at a meeting of the Horticultural Society that same year it seems to have failed to create even a ripple of

Fig. 42.—Tree worship, as a symbol of fruitfulness, was part of many ancient religious cults. This illustration, drawn from a bas-relief in Nimroud, indicates recognition of the relation of pollination to fruitfulness in the date palm, 2,000 years before the beginning of the Christian era. (*After Perrot and Chipiez.*)

interest, possibly because most of the English varieties of the time were perfect flowering. Duchesne, in France, had observed this condition during the life of Linnaeus.

Even this is far from being the first observation of the importance of cross pollination in cultivated fruits. Theophrastus wrote, about 350 B.C., of the date palm;

> . . . when the male palm is in flower, they at once cut off the spathe on which the flower is, just as it is, and shake the bloom with the flower and the dust over the fruit of the female, and if this is done to it, it retains the fruit and does not shed it (Fig. 42).

It is even claimed that male blossoms of the date palm were a staple commodity in the markets of ancient Babylon. "Caprification" was among the calendar of operations in the fig orchards of Asia Minor centuries before the Christian era.

IMPOTENT POLLEN

The condition where male and female blossoms are on separate plants is not confined, however, to tropical fruits and to straw-

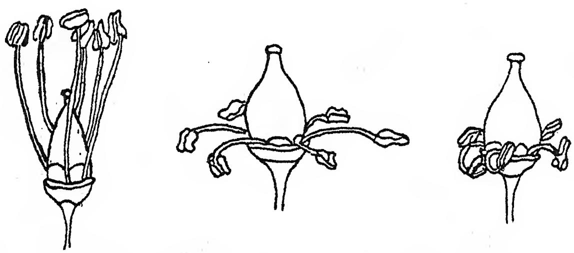


FIG. 43.—Three types of grape blossoms. At the left, Concord with erect stamens that bear potent pollen; the blossom in the center with recurved and that at the right with reflexed stamens are practically pistillate flowers, for their pollen is shriveled and impotent. (*After Stout.*)

berries. The Muscadine grape, the dominant type in the South Atlantic States, is generally characterized by what amounts to this condition, for, though the flowers are apparently perfect, their stamens bear only worthless pollen. Consequently, every Muscadine vineyard should have its proportion of staminate vines which bear no grapes themselves but without which the other vines would bear none. Incidentally, the effort to breed a perfect-flowered Muscadine makes an interesting story and is significant of the undesirability of the dioecious condition. Many of the common varieties of the "bunch" grapes likewise bear impotent pollen and their vines must be interplanted with those of pollen-producing varieties if a good setting of fruit is to be obtained. The condition that these imperfect varieties of grapes

present is strictly comparable to that of the imperfect flowered varieties of strawberries, though at first more puzzling and more deceptive because their flowers appear perfect (Fig. 43).

UNEVEN MATURING OF POLLEN AND PISTILS

Still another condition is presented by the various nut trees. Pollination in these is effected almost wholly by wind. The male and female blossoms are separate, but borne on the same tree and generally on the same branch. Perhaps the chief difficulty presented in securing a set of fruit in these plants is occasioned by the fact that in some varieties blossoms of one sex mature at a different time from those of the other. This condition is advantageous in the wild state, in ensuring cross-fertilization with the accompanying hybrid vigor in the resulting trees, but in cultivation it means that at least two varieties should be grown in one planting, to increase the chance of having some staminate blossoms shedding pollen when the pistillate blossoms are ready to receive it. Pollen might as well be shed a hundred miles away as a day too early or too late.

Even more striking is a similar condition that has recently been found to characterize varieties of the avocado or alligator pear. During certain hours of the day one set of flowers on the tree are open and shedding pollen; later in the day these are closed and another set are open and in condition to receive but not to shed pollen. Fruit setting depends on the interplanting of varieties whose pollen shedding and pistil receptivities are properly synchronized. In this group of fruits pollen might just as well be shed a week or a month as an hour too early or too late.

SELF STERILITY

The rapid expansion of commercial fruit growing in the United States shortly after the Civil War led to a gradual diminution in the number of varieties grown in the ordinary commercial orchard. The planting with a hundred varieties gave way to the orchard of very few varieties and finally there appeared in some cases large plantings composed of a single variety. Then came cases of trouble. A large young orchard, tended with great care, would be a forest of bloom in the spring, but in autumn a forest of branches and leaves only, with a lone fruit here and there, while not far away a neglected, crabbed old home orchard might be loaded heavily.

A typical case was presented by an orchard near Scotland, Va., on the James River. It was planted about 1874, and consisted of 22,000 standard Bartlett pears. Up to 1892, when it was 18 years old, it had never borne more than one-fifth of a crop. In 1891 the crop was only 1,200 boxes and in 1892 less than 100 boxes. The most vigorous trees bore no more than the least vigorous. This was the condition when the orchard was visited by M. B. Waite, of the United States Department of Agriculture.

Waite writes of his visit to this orchard:

In showing me over the place the manager pointed out two Clapps Favorite trees, at a considerable distance from each other, that had been planted by mistake among the Bartlett, and remarked that whenever there was any fruit at all in that region the Bartlett trees surrounding the Clapps Favorite fruited. In further evidence of this, the limbs of about a dozen trees around each Clapps Favorite were found to be drooping and bent downward, evidently caused by heavy loads of fruit in previous years. Precisely the same thing occurred at another point in an orchard around a Buffum tree. It was further learned that a small variety orchard, planted long before the large orchard, had been very productive; portions of this still remain. On the strength of the success of the Bartletts in this old variety orchard the large orchard was planted. In the neighborhood whenever a few pear trees of mixed varieties are planted around the houses and gardens they have always fruited well.

Here, then, was circumstantial evidence pointing to a lack of cross-pollination, as in the strawberries. On the other hand, the pear was known to bear perfect blossoms. Fortunately, however, since the Strawberry War, Darwin and continental botanists had increased the fund of knowledge concerning cross- and self-pollination and the importance of insects to these processes; Waite himself had, in the previous year, initiated some experimental work at Brockport, N. Y., concerning the importance of insect pollination in pears. In this work many blossom clusters had been enclosed in sacks, to exclude insects. Diametrically opposite results were secured with different varieties. Wherever blossoms of Bartlett, Anjou, Clapp's Favorite, and Winter Nelis had been enclosed in the sacks, no fruits formed. Blossoms of Angouleme, Seckel, and some other varieties, on the contrary, set fruit about as well inside the sacks as outside, where they were exposed to insect visits.

With these differences as a foundation, more elaborate investigations were made during the next year. In this work the blossoms under investigation were emasculated (*i.e.*, the anthers were removed) and sacked, and pollen of known identity artificially applied at the proper time. The results of this work were outstanding and divided the pear varieties studied into two groups: (1) those which set fruit satisfactorily with their own pollen, commonly called "self-fertile," such as Angouleme (Duchess), Bosc, Flemish Beauty, Kieffer, and Seckel; and (2) those which do not set fruit satisfactorily with their own pollen, commonly called "self-sterile," such as Anjou, Bartlett, Clairgeau, Clapp's Favorite, Howell, Lawrence, and Winter Nelis. Pollen taken from blossoms on a Bartlett tree, for example, applied to the stigmas of blossoms on another Bartlett tree failed to induce fruit formation, but, applied to others of the self-sterile varieties, as for example, Clairgeau, it induced a satisfactory set. Conversely Clairgeau pollen failed universally on Clairgeau blossoms, but induced a good set in Bartlett and other varieties. The self-fertile varieties set fruit either with their own pollen or with pollen from other varieties.

Even in those varieties which set fruit with their own pollen, larger and sometimes more uniform fruit is produced from cross-pollination. There was, however, little or no evidence obtained at that time that pollen of any one variety is superior to that of another variety for cross-pollination. Bartlett, for example, seemed to set fruit as well with pollen of one variety as with that of another.

Out of this investigation came also clear evidence of the importance of bees, particularly honeybees, in effecting cross-pollination. Visiting the blossoms for the nectar, they carry pollen adhering to them, from the anthers of one variety and in visiting another blossom they brush against one or more of the stigmas, which, with a sugary solution on the surface, retain some of the pollen (Fig. 41). This sugary solution not only holds the pollen but it also serves as a germinating medium for the pollen grains which after germination send growths ("pollen tubes") down into the pistil and fertilize the ovules. Without the completion of this process the fruit fails to set in the self-sterile pears.

The stimulus of this discovery led to investigation of other orchard fruits. In fact, prior to Waite's work, the fruit growers

of Illinois had formed, from field observation on American plums, a good notion of their self-sterility and were providing for cross-pollination. In the apple self sterility has not been found as widespread or as aggravated as in the pear, possibly because an unconscious selection for heavy bearing was exercised in the choice of commercial varieties for extensive planting and, since apples have been grown on a large scale in the United States far more extensively than the pear, this selection may have been more rigorous. Another explanation may perhaps lie in the fact that, in the apple, variety selection has been generally for high yields to a greater extent than in the pear. Whatever the reason may be, the fact stands. Baldwin, Ben Davis, Gano, Jonathan, Grimes, and Wagener, all of great commercial importance, are generally self-fertile. On the other hand, Winesap, Wealthy, Rome, Delicious, and Arkansas Black, as well as other varieties of nearly equal importance, appear to set fruit better with other pollen than their own, and a large amount of circumstantial evidence points toward improper or insufficient pollination as the chief limiting factor to much greater yields in many commercial apple orchards.

Among the plums investigation has revealed many cases of self-sterility. Practically all the commonly cultivated varieties of Japanese and American plums appear to be self-sterile; some of the most widely grown European varieties, however, such as the Italian and French prunes, which constitute most of the Pacific coast prune plantings, and Green Gage and Blue Damson, home orchard favorites everywhere, have been found partly or wholly self-fertile. With some unimportant exceptions, one variety serves as well as another for cross-pollination within the species, but satisfactory cross-pollination between specific groups is not likely to occur. This means, for example, that a Japanese plum will not set fruit with pollen from a *domestica* plum, such as Italian; the grower planting one Japanese plum should plant with it another Japanese variety.

Many other fruits show various degrees of self-sterility. In grapes, Concord, the dominant variety east of the Rocky Mountains, is self-fertile, as are the majority of the other leading varieties; a few, however, as Brighton, are self-sterile. Certain citrus fruits present an interesting reversal of ordinary conditions, in that pollination may become disadvantageous. Some of the seedless types, as the Washington Navel orange, produce flowers

wholly without pollen, but bear heavily when planted solidly in blocks of many acres. In these cases pollination, causing the formation of seed and not improving the set, which is good enough, would lower the commercial value of the product. Pineapples and bananas, also seedless, bear without pollination; some seedless grapes, however, require pollination.

INTERSTERILITY

About 1912, the sweet cherry presented another problem in pollination. The increased demand for preserved cherries for the soda-fountain trade, to which purpose the Napoleon Bigarreau ("Royal Ann" of the Pacific coast) is eminently suited, had led to extensive planting of sweet cherries at The Dalles, in Oregon. Guided by experience with other fruits, the growers planted enough of other sweet cherries, such as Bing and Lambert, to ensure cross-pollination. With the care given them, the orchards flourished and soon arose a custom of organizing excursions to visit The Dalles at cherry blossom time and see the hundreds of acres of cherries in bloom. A wonderful sight it was, but there were at picking time no excursions of pickers to The Dalles, because there were few cherries to pick. Something was wrong; lack of cross-pollination seemed out of question, for Napoleon, Bing, and Lambert, side by side, were alike unfruitful.

About that time there was much ado over orchard heating in deciduous orchards. It was, therefore, but natural that some growers should instal orchard heaters by the hundreds and by the thousands. The next cherry blossom season came, the excursionists arrived to see the blossoms, the orchard heaters flared and smoked—and the blossoms dropped without setting fruit. The trees were now old enough to have outgrown the caprice sometimes shown by young trees in failing to set fruit, lack of cross-pollination was obviated as a factor, and the orchard heaters had failed.

This was the status of affairs when the problem was presented to the Oregon Agricultural Experiment Station. As in the case of the pears, 20 years earlier, some work already under way at the college provided a clue and the first step toward a solution. In the course of some cherry-breeding investigations, attempts to cross Napoleon, Bing, and Lambert, done on a rather large scale, had been unsuccessful, though pollen of these varieties was effec-

tive on other varieties, and pollen of other varieties was successful on the blossoms of these. A visit to the orchards strengthened the hypothesis that was taking form. Here and there were little groups of well-loaded trees. Invariably these were characterized by the presence of a tree planted by mistake, of some variety outside the "big three" constituting the orchards, or in some cases they surrounded a tree formed by a sprout from below the graft, from the root, a seedling, lacking only a name to constitute it another variety.

Experimental confirmation of the hypothesis followed rapidly. As an emergency measure, boughs of other varieties, cut just before blossoming, were suspended in the trees or placed between them, resting in buckets of water. Wherever this was done an abundant set of fruit occurred; where it was not done, there was no fruit. This signifies, then, that some varieties of sweet cherries are not only self-sterile but also intersterile; that is, they will not set fruit with their own or with one another's pollen. An isolated trio of trees, Napoleon, Bing, and Lambert, might blossom year after year and never bear, but if a Windsor or Black Tartarian cherry was included in the group, there would be a crop on all four trees, on all four varieties. In the orchards already planted, this condition was secured by top-working occasional trees to Windsor and Black Tartarian; in the orchards established since that time a certain percentage of these other trees have been included, not because the growers want them, but because they want Napoleon, Bing, and Lambert cherries.

A similar condition of intersterility has been found in several of the leading commercial varieties of the almond and more recently in some important apple varieties, including Winesap, Stayman Winesap, and Arkansas Black. Still more recently some pear varieties, *e.g.*, Bartlett and Seckel, have appeared to be intersterile.

Fruit plants, then, present a variety of conditions which may cause crop failure, even though weather, soil, and cultural practices are suitable. This account has discussed the most important and most common of these; it should, however, be understood that there are exceptions, qualifications, complications, and minor differences not mentioned here. Fortunately for the growers of most fruits, understanding of the condition is the most difficult part of the problem. With plantings properly made, success in this respect generally follows.

Proper planting to ensure cross-pollination implies, briefly, that those varieties known to be wholly or partly self-sterile should not be planted in solid blocks. More specifically, for orchard fruits, no more than four rows of a self-sterile variety should be planted solid. A common arrangement is the alternation of four rows of one variety with four rows of another, or, when the grower wishes to have as many as possible of a single self-sterile kind, every fourth tree in every fourth row should be of the pollinating variety.

ENVIRONMENTAL FACTORS INFLUENCING FRUIT SETTING

Even proper planting for cross-pollination, however, does not guarantee a crop. Not every case of crop failure, or even of repeated crop failure, is due to failure in pollination. Frosts around blossoming time are universally recognized as fruit-crop destroyers. Prolonged rains during the blossoming period are perhaps more frequent than frosts, in most fruit-growing sections, and, while they last, they are just as effective in preventing a setting of fruit, though they do not necessarily damage the blossoms already set or not yet opened, as frost does. Fair, but cool, weather is also injurious. Whoever originated the simile "busy as a bee" did not have in mind a blossoming orchard in a cold wind, for the bees, though they may work overtime when they like the weather, do no work at all when the temperature falls below a certain point, stated as 42° F. by some and as high as 56° F. by others. Without bees, the self-sterile varieties set but little fruit. In the prairie states and the southwest, a hot, dry wind sometimes decreases the set.

Disease, too, takes its toll in some fruits. In the apple and the pear, the bacterial disease called fire blight sometimes breaks forth early and may then be spread by the very bees that bring the pollen. It works its way through the blossoms and into the spurs and where it passes there is no fruit. In these fruits the scab fungi sometimes infect the blossoms or the young fruit immediately after blossoming to such an extent that they drop. In peaches, plums, and cherries brown rot may have the same effect. Fortunately, the grower who sprays correctly ordinarily encounters little difficulty in controlling scab and brown rot.

At some times lime-sulphur sprays seem to have an injurious effect on the set of fruit in the apple and pear.

Lack of vigor may cause a failure to set; this may be remedied by timely applications of fertilizer carrying nitrogen in a quickly available form. Under some circumstances excessive vigor may be prejudicial to heavy setting; this condition, however, is far less common than its opposite.

Handled intelligently, self-sterility, whether due to imperfect flowers, impotent pollen, incompatibility or other factors, does not present insurmountable difficulties and self-sterile varieties may be profitable. Some self-sterile fruits have been in cultivation for many centuries and methods of definitely providing for their pollination are presumably as old as the art of fruit growing (Fig. 42). In spite of this, however, lack of a general understanding by deciduous fruit growers of the flower- and fruit-setting characteristics of their particular varieties and of methods of adjusting planting plans or cultural practices to them has probably occasioned losses as heavy as those induced by insects, fungi, winter cold, or summer drought. The extent of these losses is not appreciated because growers place the blame on other more obvious factors. Furthermore, enormous losses due to lack of proper pollination are never recognized as losses, because half crops are accepted as full crops, as all the trees or vines are really capable of bearing. The most regrettable aspect of the whole matter is the fact that most of these losses are preventable and that the preventive or remedial measures, unlike those that must be employed to deal with most other limiting factors, are very simple and inexpensive. They yield enormous dividends on the effort or expense that is required.

Other things equal, self-fruitful varieties should receive preference over those that require special provision for cross-pollination. Self-sterile trees can bear only in years when their pollenizers blossom and even then incidents such as a bee disease appearing in epidemic form or cold weather during blossoming may reduce their crops more than they do those of the self-fertile trees. If the pollenizer happens to be self-fertile it may bear in the year the self-sterile variety fails, and naturally it does not blossom in the next, causing another crop failure in the self-sterile trees and only in the following year will the condition be remedied. The plant breeder's work is not done until the self-sterile varieties are replaced in other fruits as well as they have been in the strawberry.

CHAPTER X

WINTER INJURY

Some of the first explorers to visit points along the Atlantic coast of North America, reported finding a tropical climate and the early plans for some of the first settlements included the growing of subtropical fruits in regions where it is now known to be impossible. The first visits occurred in summer, and Europeans, accustomed to a mild summer, naturally supposed that if the summers in the new world were hot the winters would be correspondingly mild. Actually, as compared with most of Europe, both summer and winter are more extreme in North America, and large areas on this continent have a climate which may be described as an Italian summer combined with a Russian winter. To secure such temperature extremes as many an American farmer experiences without leaving his own farm, most Europeans would have to visit points several hundred miles apart on a north and south line.

Into this region of great contrasts were introduced fruits which had originated in or evolved through a thousand years of culture in Europe. To accommodate these to American conditions through trial and elimination, was the task of several generations —and the task is not complete. It has, however, proceeded far enough to mark out some areas as unsuited to the cultivation of certain fruits. For oranges, most of the United States is unsuited. The area where peaches can be grown commercially is less restricted, though the sections of heavy production do not appear very large on a map of the United States. Even the so-called hardy fruits, such as the apple and the plum, can by no means be grown everywhere. Though many factors are concerned in the actual distribution of the fruit-growing industries, perhaps the greatest single factor has been winter temperatures. This is the bar which on the one hand restricts the orange to Florida, California, and the Gulf coast and on the other hand makes an apple tree a novelty in large areas of Wyoming, the Dakotas, and eastern Montana. Hundreds of thousands of Americans have never

seen a peach tree, because of the cold winters prevailing in their home regions.

Besides these broad territorial delimitations, however, winter temperatures exercise other effects of more immediate concern in those regions where fruit growing is well established. In many of these regions, the industry is based fundamentally on freedom from minimum temperatures below the safety point for the fruits grown there; exceptional winters visit these regions with devastating effect, as, for example, the winter of 1898–1899, which killed 45 per cent of the peach trees in Michigan. These destructive visitations are not confined to northern regions; Florida orange groves were damaged as severely in 1835 and 1896 as any northern orchards have ever been and the winter of 1912 showed that California orange and lemon groves are by no means immune to injury from winter cold.

Individual bankruptcy and community distress have often followed in the wake of these occurrences. In addition to the fatalities, many of the trees that survive are so injured that several years elapse before they recover their full productiveness, and many never recover (Fig. 46).

Very rarely, however, have even the most destructive freezes taken all the trees in a region. Many striking differences have appeared between adjoining orchards or even in the same orchard; at Traverse City, Mich., after one of the cold winters, peaches were harvested in abundance from trees in the upper edge of an orchard while many trees in the lower edge stood destitute even of foliage, dead from winter injury. Sometimes there have been reversals of the common ranking in hardiness, as, for example, when apple trees are killed while peach trees survive, or between different parts of the same tree, as when peach buds are uninjured but the wood is killed. Though these differences often appear capricious and without system, careful study and comparison generally show them to reflect some differences in location or in management that are important to the fruit grower as hints for provision against similar losses or for the best handling of already existing cases.

CRITICAL TEMPERATURES VARY

Among the apparent inconsistencies characteristic of injury from freezing is the variability of the temperature causing injury. The greatest destruction does not necessarily accompany

the coldest winter. At South Haven, Mich., the damage caused by a winter with a minimum temperature of −22° F. was very slight compared to the destruction on another occasion when the temperature did not drop below 7° above zero. At East Lansing, Mich., apple trees in the nursery were considerably damaged by a temperature of 26°, in the fall of 1925 (Fig. 44), though they ordinarily withstand midwinter temperatures considerably below zero with no injury. Horticultural annals abound with similar instances.

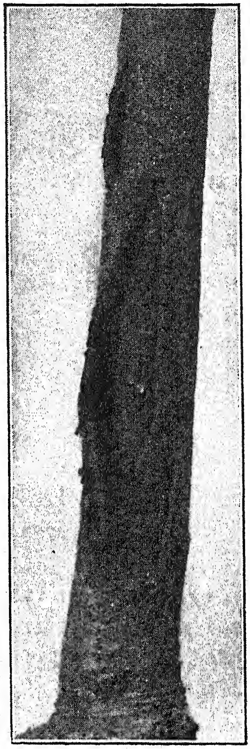


Fig. 44.—Two-year-old apple seedling, with bark cracked by an early October freeze. Callus formation started at the sides before winter. Trees with bark cracked from freezing are invariably black hearted and should not be planted.

Field study of isolated cases might explain these anomalies in several ways. Comparison of numerous field observations, however, leads to the conclusion that well-ripened or "mature" wood is relatively hardy and that tenderness increases with departure from this condition. During the growing season all plants are tender, and the so-called hardy species and varieties differ from the others only in their greater ability to prepare themselves in late summer and autumn for the cold winter that is to follow. Moreover, the geographic limit for the culture of some fruits is determined as much by the favorableness or unfavorableness of the conditions that permit or promote this proper ripening as by the actual minimum temperatures of the succeeding months.

HOW FREEZING KILLS

Laboratory investigations of frozen plant tissue offer at least partial explanation of death from freezing. Contrary to popular opinion, it is not due to bursting of the cells; actually the cells shrink. Seen through the microscope, the first effect of the lowering of temperature is the formation of ice crystals, not in the cells, but between them. With further lowering of temperature

these crystals become larger; the water to supply this growth is drawn from the cells through their walls, the protoplasmic cell contents shrinking and the cell walls being forced inward by the enlargement of the ice crystals. It is thus a case of the cells being crushed by pressure from the outside, rather than of breaking because of expansion within. If the temperature rises before the death point is reached, the process is reversed; the crystals melt, water reenters the cells, the protoplasm swells and the cell walls resume their former positions. If, however, the drop in temperature continues, a point is reached where the process is no longer reversible. Death has intervened.

Death itself has been explained in several ways. One view holds that freezing increases the acidity of the protoplasm to such a point that the protein constituents coagulate; once this occurs they will not return to their former condition. Another explanation ascribes death to the excessive withdrawal of water from the protoplasm. This view is not inconsistent with the common observation that succulent (watery) tissues are most tender to freezing, for these tissues lose water most readily and may easily be supposed to retain less at the critical time. The change from the tender condition of summer to the resistant condition prevailing in winter is, presumably, due to alterations in the water-retaining capacity of the protoplasm. This water-retaining capacity probably depends on the presence of some constituent of plant protoplasm that is a colloid and has a powerful affinity for water.

WINTER INJURY ASSOCIATED WITH IMMATURITY

Whatever the precise nature that the process of death may be, all are agreed upon the relative tenderness of immature tissue. Freezes of moderate intensity coming in the autumn may be more damaging than severe freezes in midwinter. The destruction of South Haven, Mich., peach orchards at 7° F. occurred early in October. A warm, rainy autumn is likely to lead to damage, even if the ensuing winter is normal. In almost all cases, damage has been greatest in those orchards or in those trees which were forced to late growth in the autumn. Heavy manuring or fertilization, very heavy pruning, late irrigation, and late cultivation—all processes inducing vigorous growth—have, at one time or another, been associated with injury from cold weather, and after destructive winters reports have been common to the effect

that vigorous trees were most injured. For the same reason, trees in heavy, moist soils are more subject to injury. It thus happens sometimes that trees or orchards that look the most vigorous and thrifty in summer and fall look the worst the following spring, after the effects of a severe winter become evident.

Promoting sufficiently vigorous growth to maintain fruitfulness and at the same time avoiding injury from late ripening of wood is not ordinarily difficult. Early fertilization with nitrogen carriers secures early vigorous growth in the trees, which can be checked in late summer by the growth in the orchard of cover crops, which compete with the trees for moisture and nutrients. Any crop which grows well in shade, germinates and grows well in rather dry weather, makes abundant growth in summer and fall, is not killed by the first frost, and of which the seed is not expensive, is eligible for consideration as a cover crop. In most situations oats meet these specifications rather well.

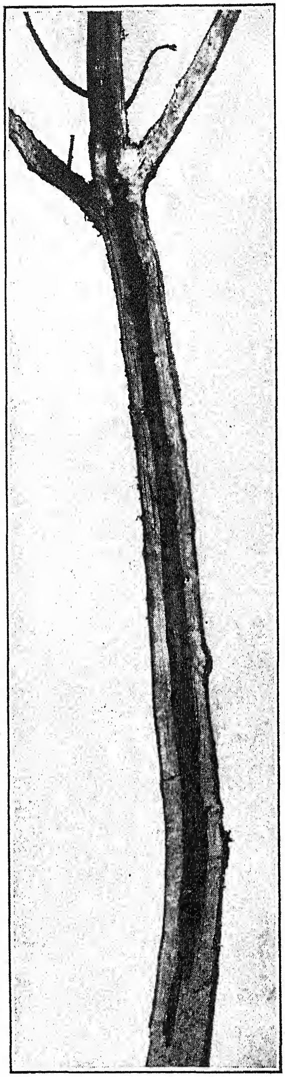


FIG. 45.—Black heart in young tree in orchard. Poor growth, despite fertilization. Some trees in this orchard are recovering slowly; others have died and more will.

TREATING WINTER-INJURED TREES

Injury from immaturity cannot always be prevented. Well located and well-managed orchards are sometimes affected when weather conditions are very extreme. Trees that are killed present no problem beyond their removal, but many trees are injured enough to require discriminating treatment, which varies according to the nature and the extent of the injury.

BLACK HEART

Newly formed wood is generally more tender than the cambium and in particularly cold weather it may be damaged, even in well-ripened trees, though the tree shows no external evidence of injury. Mild freezing of vigorous nursery stock may produce

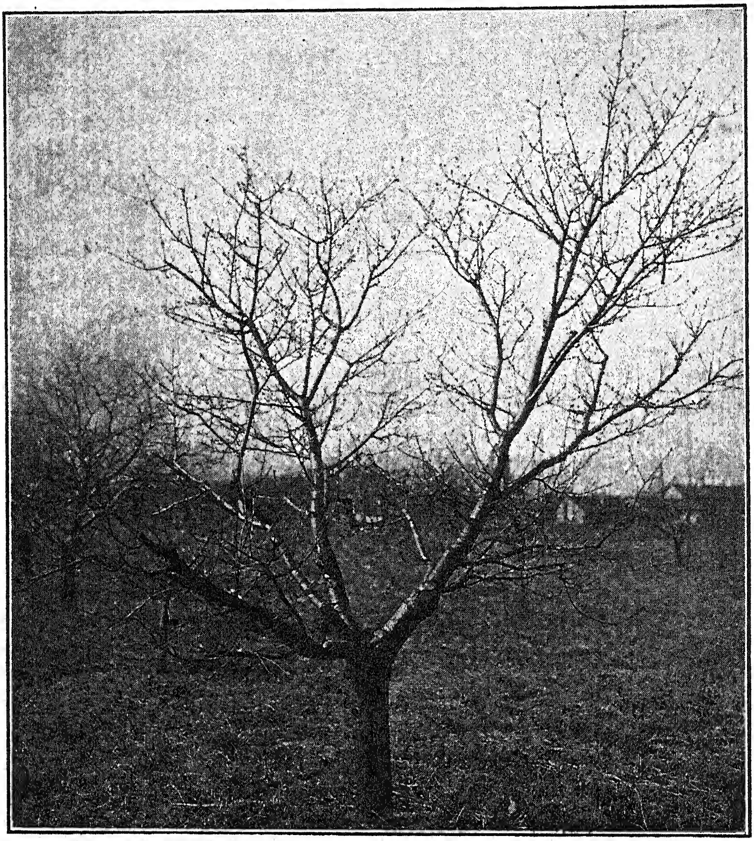


FIG. 46.—Sour cherry tree with black heart. Growth slow, wounds not healing. Somewhat tardy in blossoming. Foliage sparse and dropping early.

the same condition. It is manifested first by a water-soaked appearance in the wood, later turning brown or black, and has for this reason been called black heart (Fig. 45). Injury of this sort appears to affect in some way the conduction of water and it has been shown to make the carbohydrates stored in the wood unavailable for growth renewal in the spring. For this reason

severe pruning of seriously injured trees is likely to prove detrimental or even fatal, by removing the buds which contain in embryo the potential carbohydrate makers, the leaves. Under favorable conditions, trees with black heart that have been growing well before injury are likely to grow slowly for a year or two, but ultimately recover and have many years of usefulness. They should, however, receive good culture, and young trees with black heart should not be transplanted for a year after the injury; in fact, it is questionable whether they should ever be transplanted. Many trees are sent out from nurseries in a black-heart condition. Some of these fail to establish themselves and die in the first summer after planting; others grow well perhaps for several years, until they are killed by fungi invading the black-heart tissue through pruning wounds. Some outgrow the trouble altogether, but the planting of winter-injured nursery stock is distinctly a questionable practice.

Black heart is not limited to trees standing in the nursery row, though the vigor with which such trees are grown to meet the demands for large stock, makes them especially susceptible to it. Orchard trees of almost any age and kind may be injured in this way if they are sufficiently immature and late fall or early winter cold is extreme. Figure 46 shows a 16-year-old sour cherry tree, photographed 8 years after a freeze that led to the black-heart condition in many of the trees in this orchard. Year after year injured trees have died out and been replaced. More will follow. Some died earlier than others because their injury was relatively more severe. In this particular case, injury was due less to immaturity associated with great vigor than to another kind of immaturity associated with heavy fruit production and with premature defoliation induced by an attack of leaf-spot fungus.

Much of the danger from black heart lies in the complications which may follow it. For some years after its occurrence trees are particularly subject to its recurrence and the sparse foliage of black-heart trees renders them more susceptible to sunscald. Furthermore, black-heart tissue is particularly susceptible to attack by wood-rotting fungi, which weaken the trunk and branches. Some of these fungi, once established in the tree, attack sound wood and may ultimately kill the tree. Consequently pruning wounds which expose black-heart tissue should receive a protective covering.

COLLAR AND CROTCH INJURY

More severe injury involves the cambium. When this tissue is killed, new growth at the areas involved is impossible, and if the area killed is proportionately large, recovery is difficult. In most cases killing of the cambium is accompanied by injury of the black-heart type; when, therefore, the dead bark sloughs off, as it does sooner or later, wood-rotting fungi are provided free access to tissue rendered particularly susceptible to their attacks.

FIG. 47.—Collar of apple tree several years after partial girdling by winter freezing. Callus growth from above partly covered the injury but before it could bridge the gap the whole side of the tree died.

A tree does not ripen all its wood at once; the crotches and the "collar" or "crown"—the portion of the trunk just above and just below the surface of the soil—seem to ripen last. Consequently, early advent of cold weather often produces injury to these regions when the remainder of the tree is undamaged. This injury takes the form of "bark killing," *i.e.*, cambium killing, as previously described (Figs. 47 and 48). These areas are the most likely places for fungous invasion since they are almost constantly moist. Aside from fungous attack, however, injury at these points need not be very extensive partly to

girdle a tree or a branch just as effectively as mice or an axe would do it. Girdling any considerable portion of the trunk seems to have as its consequence the ultimate death of the portions of the tree directly in line with the girdled area above and below. This process appears to require several years; the first noticeable effect is slower growth at the tips of the branches involved (Fig. 49), then some of the tips die. At the same time the bark above the

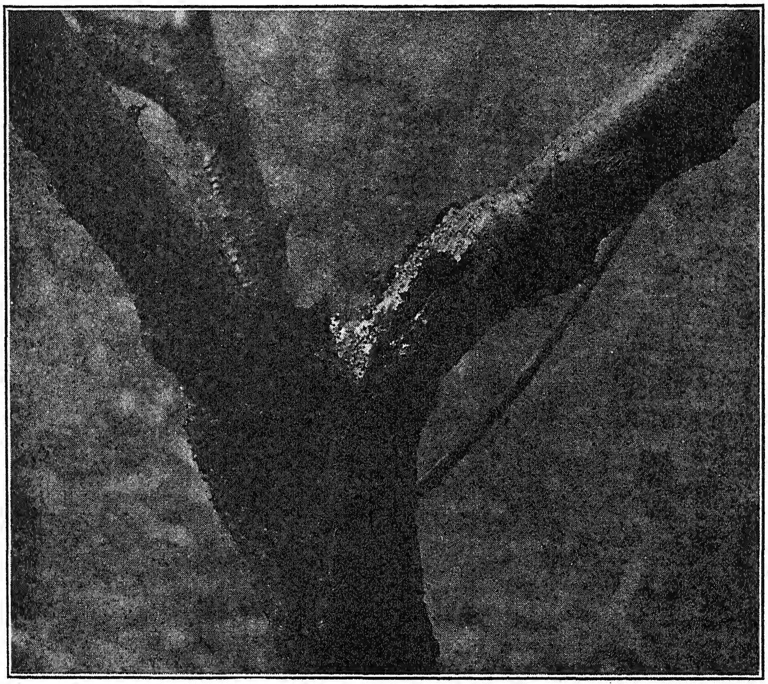


FIG. 48.—Crotch injury in a peach tree due to winter freezing.

girdled area dies, a little at a time. Finally, the tissues intervening between the dead tips and the dead bark above the girdle die suddenly, and part of the tree must be cut away.

This aftermath is preventible. The remedy is the same as that invoked in other cases of girdling, namely, bridge or approach grafting (Fig. 17).

Since some varieties are much less susceptible than others to crown and crotch injury (Fig. 51), resistant orchards of the tender varieties may be formed by planting trees of the hardy sorts and

grafting them to the tender varieties whose fruit is desired. The limbs are not rendered more hardy by this process but, since the

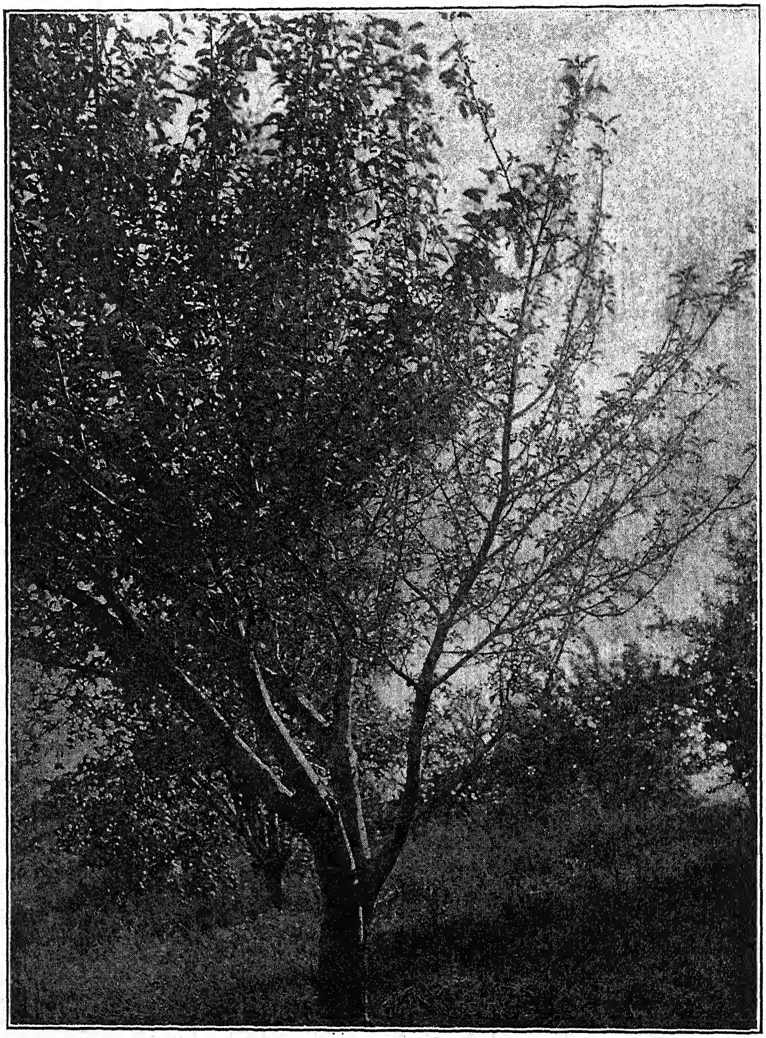


FIG. 49.—Growth has slackened in the limb at the right because of girdling at the collar on that side of the tree. Death is a matter of time only. Destruction of the roots on one side of a tree gives rise to similar symptoms.

vulnerable part of the tree is more resistant, the tree as a whole is more hardy.

KILLING FROM MIDWINTER AND LATE-WINTER COLD

Not all winter injury is due to late or insufficient ripening of the tissues. Unseasonably low temperatures in early spring after the tree has resumed its growth have sometimes caused no little damage to branches of pear and apple trees, sometimes even killing fruit spurs and 2- or 3-year-old wood. Since spring activity generally begins in the buds rather than in the wood, however, late freezes are more likely to damage the buds. Conversely, unseasonably warm winter weather frequently stimulates buds into activity and thus renders them susceptible to cold of ordinary intensity. Killing of buds under these conditions is more common in southern regions and more general in some fruits than in others.

If a number of peach trees are grown in pots and removed into a greenhouse in successive lots, beginning Oct. 1 and continuing until January, those brought in later are likely to blossom and to unfold leaves ahead of those brought in at earlier dates. Those brought in on Oct. 1 start very slowly and many of the buds never break. Lilacs destined for forcing to supply the European winter cut-flower markets were formerly held out of doors until they had been exposed to rather sharp freezing; if they were brought in earlier they did not flower satisfactorily. More recently, however, other treatments have been substituted for freezing; exposure to certain gases, such as ether, immersion in certain solutions or even in hot water, and occasionally spraying, have similar effects and permit earlier starting of the forcing process.

This accelerating effect is known as "breaking the rest period," that is to say, these various treatments bring the plants out of a condition in which they do not grow even though temperature and other conditions are favorable. Some plants have no rest period, and among those in which it exists it varies in length. Unless it is broken by some influence, it has, apparently, a definite period in a given kind of plant; the earlier it begins the earlier it terminates and if its inception is retarded its end also is delayed. The rest period is of particular interest to peach growers in the southern states, where crop losses from premature development of blossoms are rather frequent. Cultivation that prolongs the growth of peach trees late into the season delays the beginning—and the end—of the rest period and in this way postpones the time when the buds will respond to unseasonably

warm weather. Consequently, the very practices that make the wood tender make the buds, in effect, hardy.

Adjustment of cultural practices to winter conditions in any particular orchard depends on the relative probability and seriousness of the types of injury likely to occur in its vicinity. In southern peach sections, chances of bud killing are high in proportion to those of serious injury to wood and the prolongation of growth is justifiable. In northern peach sections, winters that bring enough warm weather to start peach buds are very rare, and bud killing is due to very low temperature, possibly complicated by other factors. Apparently little or nothing could be added to the hardiness of buds in the north by late growth and the very lives of the trees would be endangered.

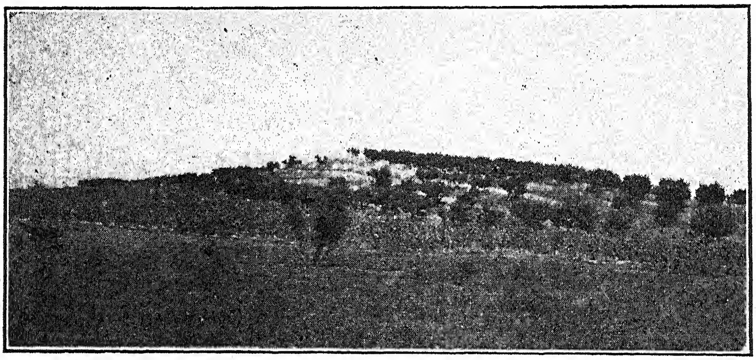


FIG. 50.—A peach orchard showing vacancies in the most exposed spots, due to root freezing, where the snow covering was blown away.

Bud killing in winter occurs most frequently in peaches and Japanese plums; in the other fruits it is less common and in the apple it is rare.

Root killing results from prolonged exposure to fairly severe cold. Roots are damaged or killed by temperatures considerably above zero and that cases of this kind are not more common is due to the fact that soil is a rather good insulator and that snow —a very good insulator—generally covers the ground during the coldest weather. Occasional occurrences of prolonged cold with no snow covering on the ground have caused widespread damage, particularly to peaches and quinces. Sporadic cases are not at all uncommon (Fig. 50). These occur in the spots otherwise most favorable, namely on high, well-drained ridges,

because snow is often swept away from these places by winds. Trees on slopes facing prevailing winds are more subject to injury for the same reason. Sandy soils lose their heat enough more rapidly than heavy soils to make trees growing in them subject to root killing. In some cases, approach grafting of young trees into the trunks of apple trees whose roots have been killed has supplied a new root system. The best preventive of root injury is the growth of cover crops which exercise a twofold protection of the roots; the vegetation is itself a good insulator and in addition holds snow. A crop which stands upright is more valuable for this purpose than one which lies flat; oats are generally better than vetch for this reason.

THE WINTER INJURY PROBLEM IN GENERAL

Winter temperature is second in importance to no other factor in setting the limits to the culture of fruits of various kinds in

Fig. 51.—The havoc caused by one severe winter. The Grimes trees in the foreground were completely girdled at the crown; Jonathan trees in the background were uninjured, being much more resistant to this form of winter killing Bridge grafting would have saved these trees.

America. It may be added that it is second in importance to no other factor in the tax that it levies on the income and profits of the fruit grower, through shortening the life and reducing the productivity of trees. Against the vagaries and extremes of winter cold, he is able to carry no insurance except proper care, and seldom is he able to afford his plants complete protection. Some alternatives are presented, however; certain contingencies

may be anticipated and certain measures and practices may be employed that will permit the evasion of most of this tax commonly levied by cold. Thousands of trees have survived many severe winters uninjured. A considerable degree of freedom from winter injury can be secured by a wise choice of location. Between sites less than a mile, a half mile or even a quarter of a mile apart there are frequently differences of 8° or 10° in minimum temperature at critical periods and this is often sufficient to decide between death or survival of the trees. Furthermore, the grower can choose varieties that are known to be capable of withstanding such extremes as are likely to occur in his location. This may eliminate from consideration certain sorts that for other reasons he might wish to grow, but the deliberate selection of more tender kinds involves the taking of chances that may cost dearly. Much can be done with proper cultural practices that aid the trees in acquiring their maximum degree of resistance to cold. If trees have suffered serious winter injury, needless waste of time and money often can be saved by recognizing the condition, and by removing the trees, repairing them, or letting them alone, as expediency dictates.

CHAPTER XI

ORCHARD LOCATIONS, SITES, AND SOILS

Civilization strews its path with relics of abandoned enterprises. The Tigris and the Euphrates flow past dead cities whose very names are unknown to the present inhabitants of those regions; Europe abounds in ruined castles, churches, and Roman villas. Even in a country as new as the United States, tumbled-down mill races commemorate the grain growing that has passed on to other regions, and abandoned villages and railway embankments indicate vanished lumbering sites and worked-out mines. Hop vines grow wild where none have been cultivated for a century, lilac bushes mark abandoned homesites, and timothy competes with wild grasses and young forest growth where fields once cropped are no longer even pastured.

Fruit growing naturally leaves less enduring monuments. With the passing of an orchard and the generation that knew it, all record generally closes. Occasionally, however, a fruit-growing enterprise gives a locality a name that persists long after the trees have gone. In England, local names such as Vineyard commemorate grape plantings where no grapes have grown within the period of existing record; in the United States local names such as Old Orchard, Peach Plain, Orchard Hill, and the like, have long survived the trees from which their designations originated.

The passing of any fruit planting is but natural and sooner or later virtually inevitable, but failure to continue the enterprise by replanting may be more significant. Inquiry concerning these changes, however, need not delve into the history of past generations, for the rise and fall of orchard enterprises is a never-ending process and occurrences of this sort were never more numerous or more significant than they have been in recent years, for which rather detailed records are available.

FACTORS DETERMINING THE LOCALIZATION OF FRUIT INDUSTRIES

In 1900, there were in the United States, according to the official census, almost 100,000,000 peach trees of bearing age; in 1910 there were 94,506,657, and the census of 1920 enumerated but 65,646,101. While the number of peach trees was decreasing the total crop was increasing. In this period the first crop to exceed 50,000,000 bushels was that of 1912; in the ensuing years the 1912 crop has been surpassed five times. Even more significant, perhaps, are the short crops. From 1899 to 1909 the crop fell below 30,000,000 bushels in three years; in the period from 1910 to 1926 it has never fallen to that point.

While some states have been losing peach trees, others have been gaining. The factors underlying this shifting, partly economic and partly climatic, are so numerous and so complex that detailed discussion of them would require considerable space. Decreases such as that in Iowa, however, where the number of trees dropped from over 1,000,000 in 1910 to 130,000 in 1920; in Kansas, where there were over 5,000,000 trees in 1900 and less than 850,000 in 1920; and in Nebraska where the number fell from 1,000,000 to 96,000 cannot but indicate very extensive plantings in places where crops—or the very life of the trees—are too uncertain. Marked decreases occurred in Illinois and Indiana. In Michigan, where the decrease was very pronounced, cold winters decimated the orchards, particularly in counties outside the recognized fruit areas, and economic readjustments have exerted important influences. This is illustrated by the fact that while the number of trees in the state was decreasing 31 per cent, the number of farms growing peaches decreased 56 per cent. Other states which are important in commercial peach production had fewer peach trees in 1920 than they had 10 or 20 years earlier.

During this period of general shrinkage in peach plantings, New York, New Jersey, and California have increased their acreages. These are important centers of commercial production. In New York, though there was a decrease in the number of farms producing peaches, there was an increase of nearly one-fourth in the number of trees. Not all the important peach-producing states show this trend so markedly, but with various allowances made, the trend may be considered to be in the direction of greater specialization; a decrease in the less-favored

regions accompanies an increase where peaches can be produced and sold most advantageously.

Most of the other fruits could be used for similar illustration, differing only in details from the peach situation. Following the pioneer from the Atlantic to the Pacific, in an almost unbroken wave, rolled a tide of fruit-tree planting. It was no mere ripple; farmers who had been raising wheat on a section of land could not content themselves with a 5-acre orchard, and trees were planted by the million. Men vied for the distinction of owning the largest orchard. Sooner or later, however, a cold winter, or poor drainage, or prolonged drought, or repeated frosts, or pest prevalence eliminated an orchard here and there; sometimes a county was swept bare, or a state nearly eliminated as a fruit producer. Repeated visitations of this kind were found to do less damage in some sections; these have remained fruit-raising regions, while the others are now raising hogs or grain or scrub oak. Ambition alone does not make a fruit region.

In some cases climate operates indirectly, through its effect on insects or fungi which prey on fruits. California begins shipping pears in June, and for some time has virtually no competition in the nation's markets. Georgia and Alabama or Texas could ship pears as early and share this advantage were it not for the prevalence of fire blight, a destructive bacterial disease, which is particularly virulent under the combination of heat and humidity prevailing in the southern states. A sour cherry tree is a novelty in many southern communities chiefly because of the virulence there of two fungus diseases: brown rot, which attacks the fruit, and leaf spot, which affects the leaves.

With broad regional eligibility for fruit growing assured there are minor variations that may make one part of a region better suited for fruit production than another. The Concord grape, for example, may be said to grow throughout the northeastern part of the United States, but its commercial production in that region is very localized. Peach trees are grown in every state east of the Mississippi River, but the commercial crop comes from a comparatively small number of specialized sections. With suitable irrigation, the prune grows virtually anywhere in the Pacific coast states, but commercially its cultivation is confined to definite centers.

In most cases these specialized "fruit belts" have developed because of minor climatic differences which have secured them

greater surety of crop or longevity in the trees. Proximity to large bodies of water tends to moderate extremes of weather, particularly on the shores which the prevailing winds reach after traversing the water. Changes of temperature are slower in water than on land; a large lake is warmer in the winter and cooler in the summer than the land. Winds blowing across it are correspondingly modified. The change from winter cold to summer heat takes place so rapidly on land that the lake remains relatively cooler in the spring, retarding the development of the buds and thereby diminishing danger from spring frosts. In autumn the lake temperatures again lag behind those of the land, and the first frosts do not visit those shores which are subject to

FIG. 52.—Rolling land along the Missouri River that furnishes some ideal sites for fruit growing. Valued at half the price of level land farther back from the river for general farming, it is worth ten times as much for fruit production.

the lake influence. These effects have made the east shore of Lake Michigan a fruit belt, a narrow region where peach trees flourish, though winter temperatures a few miles inland may utterly preclude their existence. In the Niagara peninsula of Ontario, a similar, even narrower, belt fringes the southern shore of Lake Ontario; on the plateau just above it, peach production has never been successful. The largest grape belt in New York is confined to a narrow fringe along the Lake Erie shore, limited inland by a sharp rise of ground.

Soil or topographic peculiarities sometimes limit fruit belts. The course of the Missouri River from Council Bluffs, Iowa, to its junction with the Mississippi River, is dotted with fruit-growing enterprises, whose limit is the extent of the loess, a soil

peculiarly suited to orcharding. This soil presents a more diverse topography, affording better opportunity for hilltop locations than most of the hinterland, but the soil itself is the chief factor in the superiority of the river banks (Fig. 52). Similar conditions along the Mississippi have made regions such as Calhoun County, Illinois, noted from generation to generation for the fruit produced. Without particularly favorable soil, the hilly topography along the Ohio River has effected a localization of fruit-growing effort. In irrigated regions, soil conditions and the necessity of carrying water in streams and furrows, have forced fruit growing down upon the valley floors and lower benches, where frost danger is greater than it is at somewhat higher altitudes.

Not every parcel of land, however, in a good fruit belt is suited to fruit growing. Alkali or hardpan tracts may exist; stretches of poorly drained or very sandy land may intersperse the well-drained or more fertile loams. Mere lack of elevation may spoil an otherwise desirable location. Suitability for fruit production is an independent problem for each tract of land in the majority of fruit-growing regions.

THE IMPORTANCE OF MINOR VARIATIONS IN TOPOGRAPHY

A scene in one of the successful peach-producing sections of Michigan is presented in Figure 53. Twelve years before the picture was taken the ground was fitted for planting and the choicest nursery stock of the best peach varieties was carefully set out. Each season the trees received the best care and in 7 years the orchard was a picture of health and vigor, yielding good crops of high-grade fruit. Then came a cold winter, not the coldest known in that section, but more severe than the ordinary. In the following spring a few of these trees leaved out, but so little live wood was left that for practical purposes the winter had made a clean sweep. Chagrined and discouraged, the owner applied the only remedy for the situation—an axe. He has not replanted the orchard, for, he concluded, wisely, that what had happened once would be very likely to happen again.

Within sight of this erstwhile orchard are hundreds of acres of thriving peach trees, many of them planted before this orchard was set and surviving the winter that laid it low. Furthermore, they have passed through two succeeding seasons that have been even more extreme. The destruction of this one orchard, when many near by survived, was not due to neglect, to difference in

variety, or to method of culture. It was due simply to a difference in site, particularly in elevation. This orchard was on level land, part of a very large, flat area. Surrounding this area is somewhat higher ground, on the slopes of which are the thriving peach orchards, with a record of many good crops and promise of many more. On frosty nights in spring and fall, and during periods of intense cold in winter, the cold air has drained away from the higher slopes and settled down on the level land now dotted with the stumps of dead trees. Frequently a difference of 15° F. in temperature exists between the flat and the top of the surrounding slopes and occasionally the difference amounts to 20°. Variations in winter temperature much smaller than these often

FIG. 53.—In the middle ground the stumps of winter-killed peach trees. In the left foreground are the tops of young blueberry bushes thriving under conditions that preclude the raising of peaches.

mean the difference between dead and living trees the following spring.

Slight differences in elevation do not always produce the temperature differences observed in this location. Narrow valleys are quickly filled with cold air, particularly if they are receiving "air drainage" from extensive slopes; under these conditions considerable elevation might fail to secure the advantage gained by a slight elevation on a small hill facing a broad expanse of low land or of water.

Elevation, as a horticultural term, should not be confused with altitude as measured by height above sea level. High table lands and mountain valleys at altitudes of 2,000 to 5,000 feet are liable to killing frosts every month in the year, in the same state where

the lowlands may have a frost-free season of 175 to 200 days. Elevation above the immediately adjacent territory is the important factor horticulturally.

Within a stone's throw to the right of the point from which the picture reproduced in Figure 53 was taken, on a rise of not more than 15 feet, is the edge of a 70-year-old apple orchard. The trees are sound, vigorous, and productive. They have yielded good crops for the better part of two generations and should continue to do so for two more. Careful examination reveals evidence of a few localized cases of winter injury; similar lesions probably occurred earlier and have been mended and covered over by the trees themselves. During the 60 years of their fruiting history, frost has probably levied an occasional tax on the crop. On the whole, however, the trees have been singularly free from damage by frost and freezes. No experienced fruit grower seeing the orchard would call the site ideal, especially with the stumps of the winter-killed peach trees shown in the accompanying picture in such close proximity. However, the contrast between the performance of the apple trees in the one place and the fate of the peach trees in the other, suggests that very slight differences in elevation are responsible for great differences in the suitability of land for fruit growing and that different kinds of fruit plants may vary materially in their requirements in this respect. Actually, this particular contrast is evidence of both.

Protruding above the snow in the foreground of the picture is a rather scant growth of vegetation that at first glance might appear to be weeds or brush. In reality, this foreground vegetation is the tops of some young blueberry bushes. They were planted after the killing of the peach trees and therefore were not subjected to the rigors of that particular winter, but they have passed entirely unharmed through two winters even more severe. The peach orchard originally included this area and dead trees were removed to make room for the blueberries. Here is evidence even more striking than that presented by the apple orchard that various fruit crops have different requirements as to site. It may be absolutely impossible to mature a crop of one kind of fruit or even to grow the trees in a location that may be well suited to something else. The converse statement is even more important. If the truth of this statement in its wider application could sink deep into the consciousness and orchard lore of every prospective fruit grower, there would be fewer

disappointments and disillusionments, fewer tragedies like that recorded in Figure 53.

THE BEST LOCATION MAY BE THE WORST

Evidence has just been cited showing in a general way the importance of site and more particularly of elevation in the success of the fruit plantation. The inference is that the higher the ground, in relation to adjoining areas, the greater is the degree of freedom from frost and winter injury, at least with most fruit crops. The adage that all rules have their exceptions applies here. Figure 50 shows part of an 8-year-old peach orchard, which lies 100 feet above the nearby valley; with the land sloping away from its center in every direction, better air drainage could scarcely be imagined. Withal, the trees on the top of this hill, in what would appear to be the best location, died, while those part way down the slope, particularly those on the leeward side, are alive and growing vigorously. The winter preceding the taking of this picture was one of light snowfall and of prolonged, severe cold. Under these conditions the ground froze deeper than usual, especially in windswept locations where the snow covering was thin, and in many cases the soil temperatures were low enough to kill the roots within 1 foot or 18 inches of the surface, though at no time was air temperature low enough to injure the tops directly. Under these conditions the best site so far as air temperature is concerned was the worst in regard to soil temperature and extensive winter killing resulted where ordinarily it is least expected. Had a good cover crop been standing in this orchard to hold the snow and protect the soil from such deep and severe freezing, injury would have been avoided.

Sometimes the dividing line, as determined by air drainage, between zones characterized by harmful and those characterized by non-injurious temperatures is rather finely drawn. Opening buds on the lower limbs of walnut trees are sometimes killed by frost while buds and growth equally advanced in the upper part of the tree are uninjured. Occasionally, frost destroys all the blossoms on trees at the bottom of a slope, none on the trees at its upper edge, while part of those on the trees half way down the slope are killed. Even more striking evidence of the fineness of the line occasionally drawn by air drainage is furnished by the survival of blossoms on the upper wire of a grape trellis when the crop on the lower wire is destroyed. Where the margin between

production costs and returns is narrow, minute differences like these may make an enterprise a success or a failure. Moreover, just as "the winds and waves are on the side of the ablest navigators," so are frosts and freezes on the side of the ablest fruit grower, since extensive frost damage enhances the value of the crop in those orchards which escape injury, giving their owners a double profit.

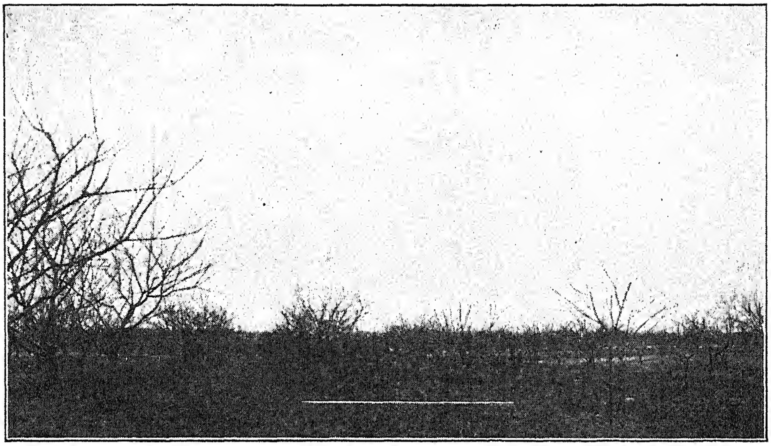


FIG. 54.—Subsoil irregularities. At the sides and in the background, vigorous 6-year-old peach trees; in the foreground, replants where the originally set trees died out because the subsoil formed a high water table "pocket." The land is level and the surface soil a fine, silty loam over the entire area.

SOILS OF DECEPTIVE APPEARANCE

On casual inspection, the soil in the orchard shown in Figure 54 seems nearly ideal. It is a fine, silty loam, porous and friable, in short, a good "garden soil," with every appearance of being well suited to raising tree or bush fruits. The surface soil is strikingly uniform over the entire area shown in the picture, and indeed over the entire 80-acre orchard of which it is a part.

Unfortunately, the surface uniformity and good qualities are only superficial. Much of this area appears to have been formed by drifting of sand over a clay ridge that had an undulating, or even rugged, surface. Just as drifting snow sometimes conceals soil-surface inequalities beneath a uniformly sloping cover, this soil is deep where it filled the crevices of the clay and shallow where it covered the ridges, though its surface slopes uniformly. Water drains off and through the surface sandy loam well

enough, but the subsoil undulations present difficulties. The filling of the old surface-drainage channels leads to water accumulations in spots, particularly where the present surface slopes in a direction different from that of the earlier surface. The result of all this is the existence of wet spots below the surface, even on the upper edges of well-drained slopes. In some of these spots excavation reveals only a loamy soil which should, apparently, drain well, and it is only upon repeated observation of the water table that the condition becomes apparent. During the summer these spots are dry enough, but fruit trees must be there throughout the year, and a high water table during part of the year is as fatal to trees as a permanently high water table, and much more deceptive to the orchardist. Once this condition is recognized, a few rods of tile, piercing the subterranean clay ridge that acts as a dam, remedies the difficulty. Where the clay is everywhere close to the surface, alleviation is more expensive or even prohibitive. Time and again trees have been set in this land, only to die before reaching bearing age, because of killing of the submerged roots in wet weather, drying out in dry weather, or freezing of the trunks in cold weather. It is an area of replants and will not change unless subsoil conditions are materially and permanently modified. On the other hand, all around the border of the area shown in the picture, peach trees are thriving, their excellent growth and productivity furnishing evidence of the general suitability of the land for the crop in question, and a tribute to the skill of the grower.

This particular case is but one illustration of the rule that for orchard and vineyard the character of the soil 6, 8, or even 20 inches below the surface is far more important than the character of the surface. Though the size and quality of annual crops and of many herbaceous perennials is determined largely by the character of the surface soil, the welfare of trees, shrubs, and vines depends principally on the character of the subsoil. Good farm land is not necessarily good fruit land. The fruit grower cannot wholly ignore the character of the surface soil in choosing a location for his orchard any more than the general farmer can ignore the subsoil in buying a farm or in deciding on particular crops for certain fields. In either case, the ideal soil is deep, well drained, and fertile; it requires no amelioration, no corrective treatment. The difference lies in the fact that the general farmer can grow many crops successfully on good soils underlaid by poor

subsoil, and the fruit grower cannot. Moreover, corrective treatments for minor defects in the surface soil are easily applied and relatively inexpensive; corrective treatments for defective subsoils are neither easy nor cheap. In the main the orchardist must take subsoils as he finds them. He should, therefore, search until he finds them as he wants them, or, if the land he already possesses has subsoils unsuited to fruit growing, he can save money by refraining from attempts at it.

As a rule, the physical structure of a soil affects the suitability of a piece of land for fruit growing more than the exact nature of its chemical composition. Fertility, as measured by the supply of available mineral elements, is important, but if some nutrients are lacking or deficient they can usually be supplied rather cheaply and readily. Deep root penetration coupled with reasonable lateral spread is fundamental to proper nutrient and water supply. This cannot be secured unless the soil has the proper texture; changing the texture of a soil is difficult.

THE IDEAL SOIL VARIES WITH CONDITIONS

Rigid specifications for the "ideal" soil, in the sense implied by mechanical and chemical analyses, cannot be formulated, because the availability of soil for fruit growing may be affected by climate. A large portion of the pear orchards in the Rogue River Valley, in Oregon, grow on a very heavy adobe soil. This may not be the best soil for pears in that section, but they grow and bear well on it and the chief local difficulties in pear growing do not concern the soil. The heavier rainfall and severer winters in Michigan would render this soil quite hopeless for any kind of fruit. On the other hand, peaches and apples succeed in Michigan on soils that would be too light in regions with intense heat and high evaporation in the summer. Even the safe minimum depth of soil varies with the climate. Orchards have died from drought in the Ozarks in soils as deep as some which overlie granite ledges in New England and support good apple orchards or as deep as the soil above soapstone in some good prune orchards in the Willamette Valley.

Furthermore, the various fruits have somewhat different requirements. In general, peaches are less tolerant of heavy soils than apples, which in turn are possibly less tolerant in this respect than pears. The dwarf pear, growing on the shallow quince root system, has been said to succeed in soils too poorly

drained for standard pears. Some grape varieties differ in the depth of their root systems and, consequently, in their requirements as to depth of soil.

These qualifications, with many others which are recognized, do not vitiate, but actually strengthen, the general truth of the fundamental necessity of deep and well-drained soil for fruit plants. That it is less important in some cases than in others is merely another way of saying that it is more important in some cases than in others; it is always important. Eventually, the orchards where the margin of safety in this respect is considerable will surpass those where it is scant, for they will survive the periods of extreme trial, which come sooner or later in all regions.

THE ADVANTAGES OF CERTAIN SLOPES

In the days of small orchards, considerable attention was given to securing a slope in the most advantageous direction, but increase in the size of the orchards, necessitating planting of slopes in all directions, demonstrated the general lack of important differences between the various aspects. The north slope, in some regions, may have somewhat deeper soil and withstand drought better, but in these same regions there are good orchards on other slopes. Greater exposure to strong wind may affect the number to windfall fruits to some extent. In regions where root killing is likely to occur, the southerly slopes, because of their frequently scantier snow covering, are most liable to this type of injury. Buds start somewhat earlier on south slopes, increasing the liability to damage from late freezes and frosts, but in some, at least, of the northern regions the difference thus induced is very rarely marked enough to affect the crop. In northern regions, crops for which the average growing season is no longer and no warmer than is necessary to ripen the crop, as for example, grapes in Michigan, may prosper better on southerly aspects. After all, however, it must be admitted that every point of the compass is faced by successful orchards and vineyards.

Circumstances sometimes force—or tempt—the fruit grower to utilize locations which are plainly defective in one respect or another. Recognition of the peril involved may lead to special adjustment which will diminish the danger. The orchardist should realize, however, that in assuming this added difficulty he is combating influences, natural or economic, which are relentless and untiring and have wiped out great numbers of

orchard enterprises that were almost well founded. Just as a chain is no stronger than its weakest link, an orchard may be limited in its capabilities throughout every year of its existence by injudicious location. Carrying an unnecessary handicap is likely to increase labor or investment or running expense, and at the same time diminish the chance of success. Prospect of unusually good returns may warrant speculation, but with ordinary returns only the well-located orchards are successful for long.

CHAPTER XII

PROPAGATION

For a century or more after the landing of the first English settlers, fruit was grown in America chiefly for beverage purposes, apples for cider and peaches for brandy. To furnish these orchards, trees were grown from seed brought from Europe and to meet these needs the trees so raised were ample. For cider purposes an apple was an apple and little importance was attached to the kind of fruit a tree bore, whether the apples were sweet or sour or bitter, whether they were red or green or yellow, whether they ripened in October or April. All contained juice and from that juice cider could be made. In an orchard of a hundred trees there were generally some that bore fruit suited to more special purposes; sweet apples that would keep into the winter were set aside to eke out the turnip supply as cattle feed—ensilage was unknown—and the fruit from certain trees was prized because it lent itself particularly well to manufacture into the dried product that was strung under the rafters in the attic; here and there was a tree bearing fruit that was good for eating out of hand.

For these purposes, the orchard raised from seed supplied sufficient assortment for the farm needs. As cities grew up, containing people who had no orchards to supply them, a market developed, and apples possessing special qualities came to have a cash value. As these cities grew larger the local supply became inadequate. Furthermore, shrewd skippers found that they could sell apples advantageously in Liverpool, New Orleans, and Havana, if the apples were pleasant to look upon and to eat and if they stood the voyage well. To meet these various demands, the old seedling orchard, with no two trees bearing the same kind of fruit, was wholly inadequate. Perhaps two or three trees in a hundred bore fruit that had cash value, but the apples on the other trees were fit only for cider or for stock feed or for immediate consumption. If the whole orchard only bore the same kinds of fruit as the two or three valuable trees, the value of the orchard would be greatly enhanced.

Unfortunately, trees raised from seeds of these especially good apples could not be counted on to bear fruit like the parent tree. A fine, red winter apple might produce trees bearing green or russet or yellow or red apples, with various flavors and of various keeping qualities. The original orchards, with their never-ending variety of apples, had been raised presumably from seed of good apples. In the interest of standardization of the product,

FIG. 55.—The graft union on the trunk of an old tree, characteristic of the orchard of two and three generations ago.

therefore, recourse to the long-known, but—in America—rarely practiced, art of grafting was necessary. Twigs from a valuable tree were so set in other trees that they grew; all the branches that grew out from these twigs bore apples of the same kind as those borne by the tree from which they came. By this process, which Shakespere called "the art which doth mend nature," thousands of worthless trees were converted into valuable producers. Similarly seedlings of 1 or 2 or 3 years' growth were

grafted before they were set in the orchard and the whole tree, growing from the one cion, bore fruit of this kind.

From want of time, or skill, many farmers were unable to do this work; the grafting over, or top-working, of older trees was done, generally, by itinerant grafters, and thousands of trees with waist-high or breast-high swellings of the graft union that are still standing in the older orchards constitute a living monument to their work (Fig. 55). The new plantings, however, came increasingly to be made with trees bought from nurseries, where they had been already grafted.

In these ways, then, the countless thousands, or even millions of Baldwin, Roxbury Russet, Rhode Island Greening, and Yellow Newtown apple trees came to fill the orchards of New England, the Hudson River Valley and the new regions of western New York. Similar processes were going on in the orchards of Pennsylvania, New Jersey, and Virginia. Nearly a hundred years after the death of the original Baldwin tree, which was a chance seedling in a Massachusetts pasture, fruit like that on the original tree is picked from thousands upon thousands of trees which, above ground, are the same.

In this respect the orchardist's problem has not been materially different from that of the vegetable grower, the grain grower, or the stock raiser. All are interested in maintaining their standards of quality, in preserving the excellence of their best individuals, so that each generation of plants may be at least as good as the one it succeeds. The difference has been in the way in which the problem has been solved. Grains, vegetables, and animals must be carefully selected and bred, a process requiring much skill and patience and sometimes yielding rather indifferent results. For the fruit grower, the perpetuation of a valuable individual is a comparatively simple matter, for he, in effect, divides the original tree, making new trees; by grafts or cuttings he produces plants that in kind are exactly like those from which they came, exactly like one another, and yield a uniform standardized product. They are literally "chips off the old block."

Grafting thus serves the fruit grower primarily for the perpetuation of desirable trees and for their increase, so that the product of the orchards can be, in some measure, standardized. It has, however, other special uses which are hardly less important.

GRAFTING TO OVERCOME DISEASES AND INSECTS

Grapes grow from cuttings. When the original Concord grape vine was found to have merit, pieces of the cane were placed in soil where they took root and each produced a new vine bearing Concord grapes. These cuttings sold at $5 each for a time, but in a short time cuttings from the new vines were available, and the supply increased so rapidly that in 10 or 15 years cuttings of this same variety were selling at 2 or 3 cents each. Some varieties of grapes form roots more readily than others, but the process is feasible commercially with practically all varieties grown and with currants and gooseberries as well.

For centuries grapes were grown in France from cuttings; nevertheless thousands of people now living have seen the vineyard industry resort to grafting. The transition from the simple and inexpensive process to the more complicated and expensive system was forced by an insect. In America, wild grapes have developed and thrived despite a root louse, known commonly as phylloxera; presumably because of this they have developed a rather high resistance to its effects, so that it is rarely a serious pest on these grapes. European grapes, however, had developed in the absence of this insect and when it did cross the Atlantic and became established in the vineyards of France, the infested vines quickly succumbed. So extensive became the loss that the wine industry was threatened; on many farms the grape was the principal source of income, and destruction of the vineyards presented a serious economic problem involving one of the leading industries of France. Control measures were impracticable until it was demonstrated that the European grapes could be grafted on certain American stocks and that the resulting vines had resistance to phylloxera because of the American roots, and at the same time the nature of the fruit was not changed. It is no exaggeration to state that this stratagem saved the wine industry of France, if not of all Europe.

In a similar way, the apple industry in Australia is, in no small measure, dependent on a special apple stock, produced in a special manner, to guard against serious damage or destruction from woolly aphis attacks on the roots.

Diseases, as well as insects, have an influence in determining which stocks are best in some cases. A large proportion of the English walnut trees grown on the Pacific coast are on Northern California black walnut roots, which resist the "mushroom root

rot" better than the roots of the English walnut. The prevailing stock for oranges in California and Florida is the sour orange, which is used chiefly because of its resistance to "foot rot." In many of the pear districts of California certain strains or types of the Japanese pear are desirable stocks because they are more resistant to fire blight than the ordinary pear (*Pyrus communis*); in some of these districts, however, the great susceptibility of these Japanese types to mushroom root rot renders their use impracticable.

GRAFTING TO MAKE PLANTS HARDY OR FRUITFUL

Sometimes climate or soil peculiarities dictate the choice of stocks on which fruits are worked. In some of the vineyard districts of France, stocks are chosen not alone for phylloxera resistance but also for ability to flourish in calcareous soil; only a few can meet this twofold requirement. In the north-central part of the United States many apple trees are grown on roots of the Siberian crab apple because of its great resistance to injury from freezing. Use of the cheap Marianna stock for plum trees is precluded in northern states by its tenderness.

Trees of tender varieties of apples, such as King, Baldwin, and Grimes, formed by grafting these varieties into the branches of hardier sorts, have survived winters that killed root-grafted or budded trees of these varieties. The hardiness of the part above the graft is not affected by this practice, but a hardier variety is substituted in the vulnerable portion—the trunk—and the hardiness of the tree as a whole is thus increased by this "double working." The process is comparable to strengthening the weakest link in a chain. The other links are not affected, but the chain, as a whole, is stronger. In a similar way and for similar reasons, orange trees formed by budding into the tops of the relatively hardy trifoliate orange are, in effect, rendered more hardy.

The stature of the tree desired is sometimes the determining factor. Pear trees on quince roots never attain the size of the same varieties on pear roots (Fig. 56); apple trees on roots of the so-called Paradise and Doucin apples are dwarfed. Consequently, for planting in a narrowly limited space, trees on these stocks are sometimes used.

Fruitfulness is sometimes affected by the stocks used. Dwarf pear and apple trees, making slow growth, generally come into

bearing earlier than "standard" trees of the same varieties but remain small, and never attain the productiveness of the mature, standard tree. On the other hand, some grapes, such as Campbell Early, make much larger and much more productive vines when grafted on certain vigorous stocks than they do when grown as "direct producers," *i.e.*, from cuttings.

FIG. 56.—On the left a row of 18-year-old standard Bartlett pear trees growing on ordinary pear seedling roots; on the right a row of dwarf trees of the same age and variety, growing on quince roots. Note the difference in size.

Grafting may influence fruitfulness in other ways than by the stocks used. Sometimes the introduction of a pollenizing variety is necessary to ensure fruitfulness, as in many cherries and plums. The pistachio and the fig are dioecious and male trees or male branches are needed to render the female trees fruitful. Mistakes may be rectified by grafting. Sometimes the grower's judgment is poor and he orders a poor variety, and sometimes

the nurseryman delivers the wrong variety. These mistakes are generally not detected until the trees begin bearing; at this time it is generally less costly to graft trees of many kinds over to profitable varieties than it is to take them out and replant. Furthermore, considerable time is saved in producing tops of bearing age and size of the desired variety. It is to correct these mistakes that grafting now finds its greatest use in the hands of fruit growers, for most of the grafting that is for the propagating of new trees is done in commercial nurseries.

THE CHOICE OF STOCKS

Most fruits can be grafted on several distinct stocks. Pear grafts, for example, grow not only on pear, but also on quince, mountain ash, apple, and Siberian crab apple. Plums grow not only on the various species of plum, but also on peach, almond, and apricot. A given species or variety, however, is not, as a rule, equally congenial to the various stocks to which it might be united. The pear is almost invariably short lived on mountain ash and apple, and some varieties, such as Bartlett, make a poor union with the quince. Similarly, the apricot makes a poor union with the almond; consequently, to produce an apricot suitable for planting in dry soils near the Mediterranean shores of France, recourse is had to double working; the apricot is grafted, not directly on the almond, but on a peach which has already been grafted on the almond. The apricot makes a good union with the peach and the peach makes a good union with the almond.

The variety of possible stocks in many cases permits some latitude in choice between them. Final decision, however, frequently depends on several considerations. Obviously the union must be congenial; in addition the stock must have adaptability to the location in which it is placed. Plums on peach stocks are generally less successful in heavy soils than those on some of the plum stocks. In France all grape stocks must be phylloxera resistant, but soil differences necessitate the use of one stock on chalky soils, another for chronically dry soils, another for wet soils, and so on. Sometimes the cheapness, ease of propagation, or initial vigor of growth rather than the ultimate character of the tree in the orchard, determines the stock used. There has been rather general agreement on the St. Julien as the best stock for plums of the domestica group, but the high cost of the seed-

lings and the difficulty of handling them in the nursery render it unprofitable for the nurseryman; as a result it is not used. On the other hand, the cheapness of peach seedlings, the ease with which they receive buds, and the vigorous trees they produce in the nursery row have caused them to be very widely used—more generally, perhaps, than they justify by their performance in the mature orchard.

INFLUENCE OF STOCK ON CION

Differences in the character of the fruit produced, depending on the kind of stock used, are generally negligible or wholly absent, judged by commercial standards. Minor differences in time of ripening and, therefore, in the flavor or color, are sometimes reported, but in comparison with the vastly greater amount of negative evidence they are relatively unimportant. The fears entertained at the outset of the grape grafting in France, lest the American grape stocks should impart an undesirable flavor to the European grapes growing on them, have proved unfounded. Similarly, the misgivings felt in Florida and California lest the sour-orange stocks might reduce the sweetness of the oranges growing from the grafts set in them, were baseless.

The independence of the various parts with respect to the final products of plant metabolism is well illustrated by an experiment on cinchona trees in the East Indies. The bark of some trees has a high quinine content, while that of others yields relatively little; these differences are maintained in trees propagated by budding or grafting. An inquisitive planter tried the experiment of working a high-yielding strain upon a low-yielding strain and after the scion had made some growth it in turn received a graft from the low-yielding strain. All foliage and branches were removed from the high-yielding section of the tree trunk; this section, then, received from below crude sap taken up by and conducted through a low-yielding section and from above it received foods elaborated in the other low-yielding section. Absorption, conduction, and elaboration, were in the low-yielding portions of the tree; nevertheless, the section from the high-quinine strain produced high-yielding bark (also see Fig. 57).

The fruit-bearing portion in the grafted tree is even less subject to influences from the stock than the bark in the case just cited. It has its own foliage and does its own elaborating of nutrients into food and, therefore, may be assumed to have

considerable independence. It is conceivable—though not yet definitely established as a general occurrence—that a slow-growing or early maturing stock may check growth in the top, and in this way produce earlier or more complete ripening in the fruit. If

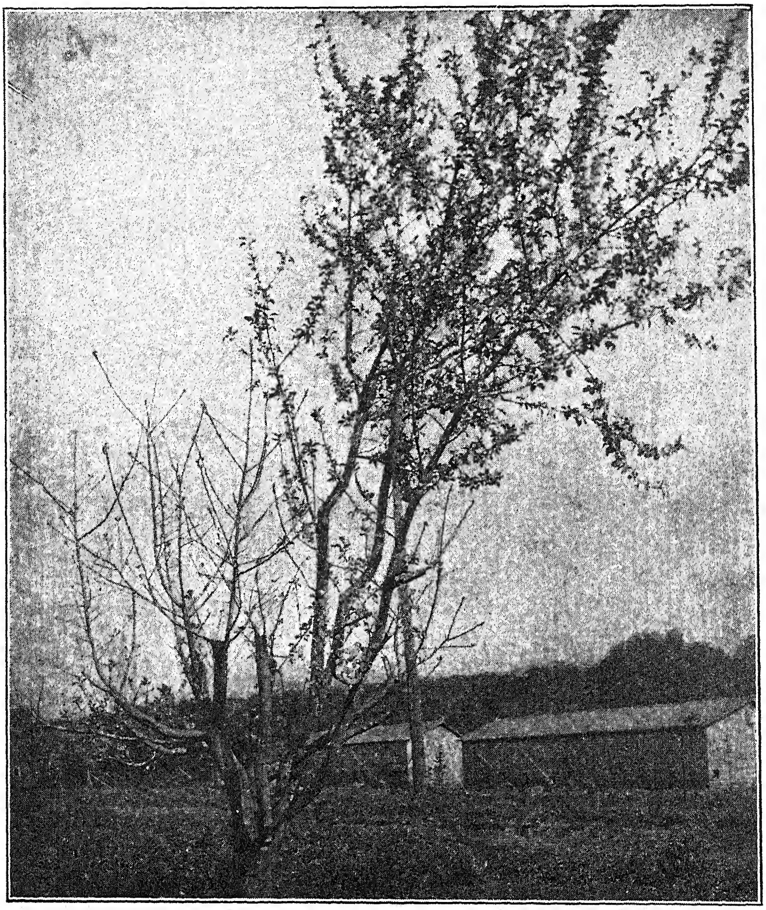


Fig. 57.—Independence of cion and stock. The early vernation of the stock has not noticeably hastened the unfolding of buds on the cions grafted into it, though it must be conceded they might have been later still on a later stock.

this condition does occur, the stock may influence the quality of the fruit but not as directly as has been assumed sometimes. An early ripening stock, bearing green apples, might in this way influence the grafts to produce redder, sweeter apples. In any case, the mere fact that a given tree produces green apples should

not deter the orchardist from grafting it to a red variety, nor need he fear that the quality of some good variety will be injured if grafted on a variety whose fruit is inferior or worthless.

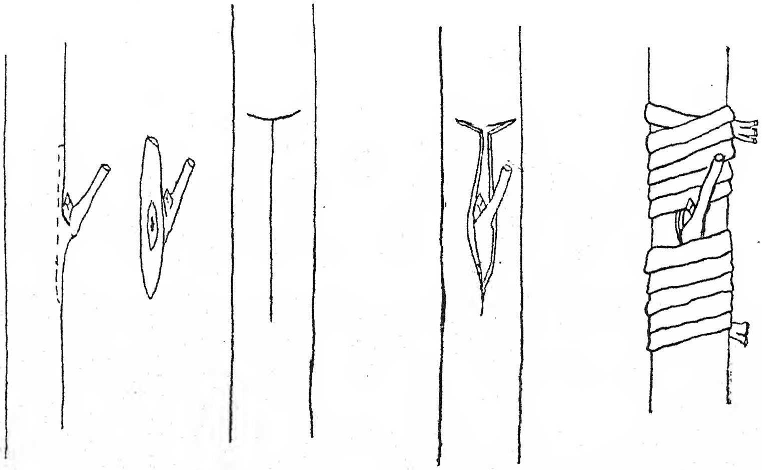
On the vigor and size attained by the tree and, therefore, indirectly on its yields the stock has, in some cases, a very pronounced effect. Quince roots dwarf the pear tree and make it bear fruit earlier than it does on pear roots, though the quince has no dwarfing effect on the loquat. The so-called "Paradise" apple produces dwarf trees when grafted to standard varieties, and the Doucin produces trees intermediate in size between the Paradise dwarfs and those worked on ordinary apple seedlings. Cherry trees on Mazzard roots are larger than those of the same varieties on Mahaleb roots. In a few cases, however, the dwarf character is inherent in the cion rather than produced by the stock; there are, for example, some peach varieties which are dwarfs regardless of the stock on which they are worked and some apple varieties—as the Wagener—never attain the stature of some others—as the Northern Spy.

Though more than nine-tenths of the grafting is done in the nursery, and stocks for this grafting are chosen by the nurseryman, the grower is the one who buys and plants the trees and loses or profits by their later performance. The success of his orchard enterprise may depend as much on the kind of roots on which his trees have been propagated as on the varieties that constitute their tops. For this reason he should acquaint himself with the characteristics of different root stocks as well as with the characteristics of different varieties, find out which are adaptable to his soil and climatic conditions, and then purchase accordingly. He should realize the importance of these differences keenly enough to be willing to cooperate with the nurseryman who is willing to grow trees designed to be profitable in the orchard rather than those that can be sold easiest or cheapest. This cooperation may involve paying more. The anxiety of the grower to get large trees at small outlay and his indifference to the stock have deterred nurserymen from helping the grower as much as they might have done. Furthermore, the orchardist should learn to set cions and to care for the developing grafts, because the orchard that contains none but the kinds of trees that were ordered, or that are wanted, is the exception and working over is in many cases the most practicable remedy for the situation.

CHAPTER XIII

NURSERY PRACTICES AND NURSERY CATALOGS

A visitor to a fruit-tree nursery during August is likely to notice in the rows of young trees, groups of men who evince a most remarkable ability in standing for hours with their legs straight, bodies bent at the hips, and their hands busy at the base of the trees. These men are "setting buds." With great



I II III IV V

FIG. 58.—Steps in budding: (I) bud stick, showing taking of bud, with cut starting below; (II), bud removed; (III), stock with T-shaped incision in bark; (IV), stock with bud inserted; (V), stock with bud inserted and tied with raffia.

dexterity one of them removes a piece of bark, so cut that it includes a bud, from a twig that he carries, and inserts it in a T-shaped cut he makes in the bark of a tree in the row (Fig. 58), and then he moves on to the next tree in the row, which he treats in like manner. Following him is a boy whose nimble fingers twist a band of raffia around the tree at the point where the bud was inserted, in such a manner that it presses the bark

down, "shutting out the air" and presses the bud close against the tree.

If this work is well done—which means generally if it is done so that the inner portion of the piece of bark containing the bud presses close against the wood where the bark of the tree was

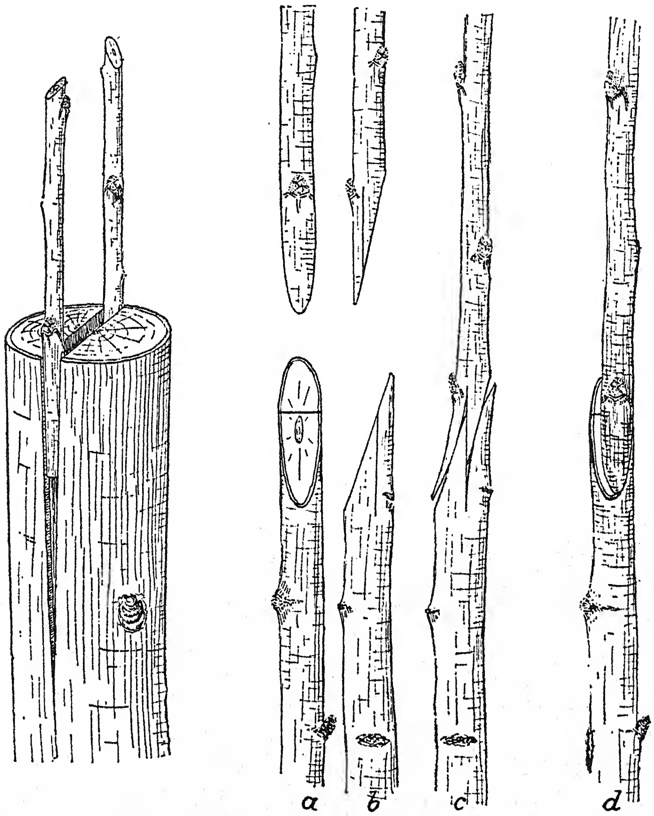


Fig. 59.—Left, cleft graft ready for waxing; right, whip or tongue graft; *a*, *b*, front and side views of stock (below) and cion (above); *c*, *d*, cion inserted in stock, ready for waxing or for tying and waxing.

cut and lifted—the bud "takes," *i.e.*, it unites with the tree, in about 2 weeks. The ties are then cut. In the following spring the tree will be cut back to a point just above the inserted bud and the vigor of the root system will be concentrated in forcing growth from this bud. Everything growing from this bud will partake of its nature; if it came from an Elberta peach tree, the

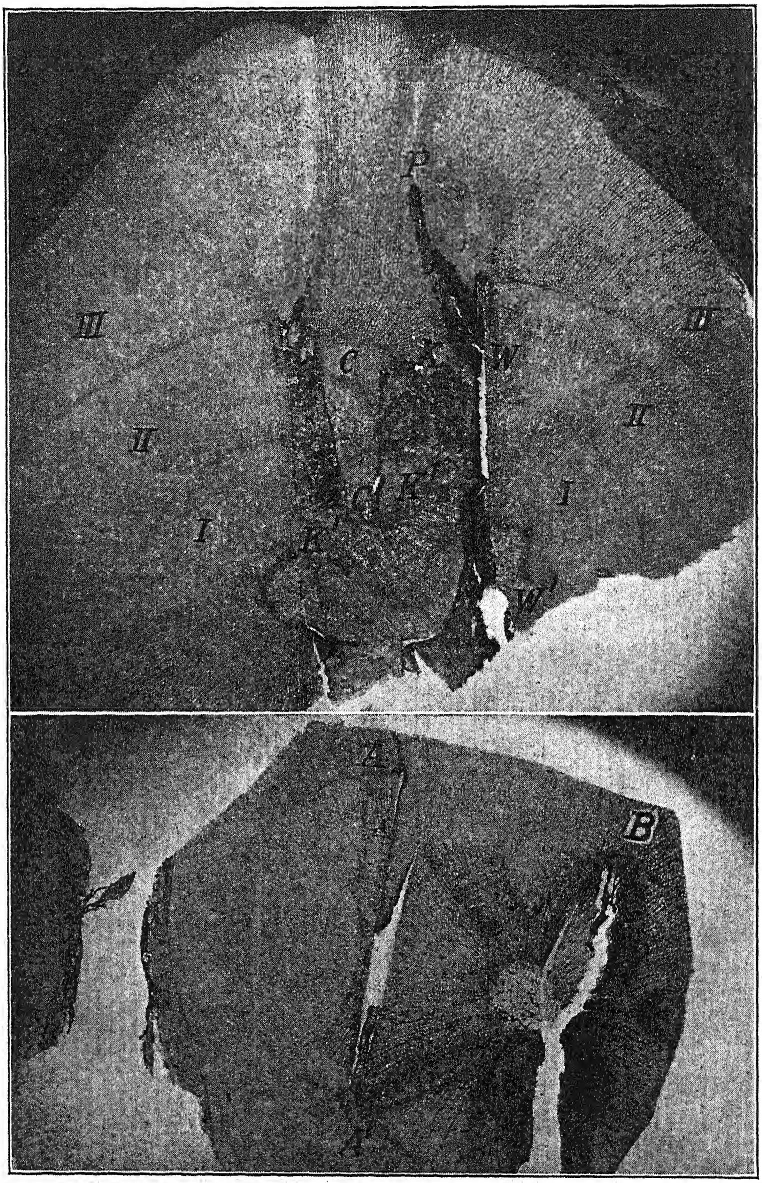


FIG. 60.—*Above.* Cleft-graft union (in cross-section) at end of first year's growth (*cf.* Fig. 59). The stock was 2 years old when grafted. There was apparently no contact between stock and cion at the level of this section, though it is possible that the callus growth (*KK'*) from the cion (*CC'*) has wedged the stock away from the cion. Most, if not all, of the callus has grown from the

new tree will ultimately bear Elberta peaches; and if it came from a Salwey tree, the new tree will bear Salwey peaches.

Practically all the stone fruits and a large portion of the apple and pear trees produced in American nurseries are propagated by this process, known as budding. Some of the apples and pears are produced by grafting.

ROOT GRAFTING

As done in the United States, nursery grafting is generally carried on in the winter, indoors. A piece of apple root, 2 to 4 inches long, is grafted with a cion, or piece of twig, generally about 6 inches long, cut from the growth made during the last summer. Sloping cuts are made on the upper end of the root and the lower end of the cion, each is slit for a short distance, and they are joined, the tongue of each fitting into the corresponding slit on the other (Fig. 59). The chief precaution necessary in this operation is to make sure that the inner bark of stock and cion meet, on one side at least. It is not necessary, however, that stock and cion be of the same size. Formerly these grafts were wrapped with string, but in recent years many nurseries have omitted the wrapping. As they are completed the grafts are set away, packed in clean moist sand or sawdust, in a cool place. Before long a callus grows out from the stock and another from the cion; when these coalesce the grafts have united (Fig. 60). In the spring the "grafts" are planted in the nursery row, generally with only the top bud protruding; here they grow and produce root-grafted trees.

In Europe a more common practice is to allow seedlings to grow several years in the nursery and then to graft them, sometimes 3 or 4 feet from the ground. This is in line with the European practice of planting older trees than American fruit growers use. It is based apparently on the supposition that seedlings are hardier than the varieties worked on them and that

cion. There is no true union between stock and cion (see *WW'*) except in the wood which develops after the graft is set. Even this sort of union was delayed on the right side, at the level of this section, until growth reached the point *P*. Mechanical pressure and moisture hastened this union. The so-called "wound stimulation" is exemplified by the shift in the location of the zones of maximum thickness of annual rings in the second and third years (II and III).

Below. Section of tongue graft cut at level which did not include the tongue. Stock at left, cion at right (indicated by difference in annual rings). This section shows union between stock and cion at *A* and *A'* and of cion with itself at *B*. The cion was somewhat smaller than the stock (*cf.* Fig. 59 *d*).

the resulting tree is, therefore, hardier than one grafted lower; in the United States hardiness is generally one of the qualities requisite in a variety and since a large number of the varieties used are hardier than the average seedling, the effect would be just the opposite.

STOCKS FOR FRUIT TREES

Despite the wide range of possibilities offered, the kinds of stocks used for fruit trees in the United States are comparatively few. For the apple, the common stock is the seedling apple; for the pear, seedlings of several pear species; and for the peach, seedling peaches are used. The Mahaleb cherry is the prevalent stock for the cherry, though on the Pacific coast, where root killing is less common or unknown, the Mazzard cherry is preferred. The plum, of which several species are grown, presents the greatest variety of stocks in actual use. For Japanese plums the peach has been rather widely used as a stock, and the Myrobolan plum is probably the most common stock for other commercially grown sorts of plums.

The production of these seedling stocks is a specialized business. A large portion of them have been imported from Europe, where, because of relatively low-priced labor, they can be grown more cheaply than in the United States. The seed are planted close together in rows and the cultivation given the young plants is much like that of an ordinary field crop, such as beans. At the end of the first growing season the seedlings are dug, or plowed out, graded, bundled, packed, and shipped to nurserymen. In the spring the nurseryman cuts away most of the tops and plants the roots; in good soil and with good cultivation, they grow sufficiently to be budded in the following summer. An apple seedling, for example, grown in 1927 from seed produced in 1926, is dug in the fall of 1927, cut back and planted in the nursery row in the spring of 1928, and budded in the summer of 1928. In the spring of 1929 the seedling is cut back to the inserted bud and from this grows the fruit-bearing portion. The tree is ready for sale as a yearling whip in the fall of 1929 or as a 2-year-old in the fall of 1930. The root-grafted tree is ready for sale a year earlier. The seedling raised in 1927 is root-grafted the following winter, lined out in the spring of 1928 and, under favorable conditions, is ready for sale in the fall of the same year. Actually, however, in many northern nurseries, growth

the first year after grafting is generally too slow to produce a saleable tree that year.

The young peach tree has a somewhat different history. Peach pits, which, for eastern nurseries are generally gathered from wild trees in Tennessee and North Carolina, are planted in the spring and the resultant seedlings budded in August and September of the same year. In the following spring they are cut back, and they make enough growth from the bud during the summer to be ready for sale in the fall. Briefly, the history may be summarized thus: pit planted in the spring of 1926; seedling budded August 1926; seedling top removed in the spring of 1927; tree ready for sale in the fall of 1927.

These stories may be compared readily from the diagram:

	Peach	Apple	
		Root grafted	Budded
Spring 1927	Pit planted	Seed planted	Seed planted
Late summer 1927.	Seedling budded		
Winter 1927–1928.	....	Grafted	
Spring 1928.......	Seedling top removed	Planted in nursery row	Seedling planted in nursery row
Summer 1928.....	....	....	Budded
Fall 1928.........	Ready for sale. Dug.	Ready for sale? Dug?	
Spring 1929.......	....	....	Seedling top removed
Fall 1929.........	....	Ready for sale. Dug.	Ready for sale? Dug?
Fall 1930.........	....	....	Ready for sale. Dug

Though the materials used and the processes involved in producing fruit trees are comparatively simple, the resulting nursery trees are not all alike or equally suitable for all conditions, and numerous questions present themselves to the prospective planter in making up an order from the nursery catalog. These are in addition to those respecting his choice of varieties.

ONE- OR TWO-YEAR-OLD TREES

If he is ordering apple trees, he must decide between 1- and 2-year-old trees and some nurseries beguile him with trees still older. Despite abundant experience to the contrary, many

people still entertain the notion that the older trees will bear earlier in the orchard. Many districts have wholly discarded the 2-year-old tree, however, and aside from its appearance there is little to recommend it. In favor of the yearling can be counted the lower cost, quicker recovery from "transplanting shock," and a better opportunity of training the tree to a modified leader type. The 2-year-old tree grown in the nursery row has its lower limbs shaded out or trimmed off, making the attainment of proper spacing between scaffold limbs a difficult matter. Older trees, guaranteed to bear the year they are planted, may be nice toys for the backyard farmer, but they have no place in the commercial orchard. Peach trees are universally planted as 1-year-old trees.

GRADE OF NURSERY STOCK

Fruit trees are sold in several grades, determined by height and "caliper," *i.e.*, the diameter at the collar, usually expressed in sixteenths of an inch, and the price increases with the size (Fig. 61).

The smaller trees are always open to suspicion. If the small size is due to their growing in poor or dry soil they may, under favorable circumstances, grow nicely in the orchard and make profitable trees, though proper training is generally more difficult with undersized trees. If, however, they are the culls from among larger trees, they may be permanently inferior because of the nature of the stocks on which they are worked. Seedlings vary greatly in vigor as well as in the character of their fruit and an inferior seedling stock may produce an inferior orchard tree. Consequently the planting of a small tree cannot, under ordinary conditions, but be regarded as a gamble.

On the other hand, nurseries sometime produce trees that are too large to be handled advantageously. Besides lacking in hardiness for fall planting, the oversized trees are likely to give trouble in forming a good framework. The buds along the trunk, which do not start until the following year in the tree of moderate vigor, are likely to "break" in very vigorous trees, and branches grow out a year ahead of their proper time. These are generally either shaded out during the same season or likely to be broken in handling the trees after they are dug. The result is that when these trees are headed back to their proper height there are few or no buds to send out branches. Under these

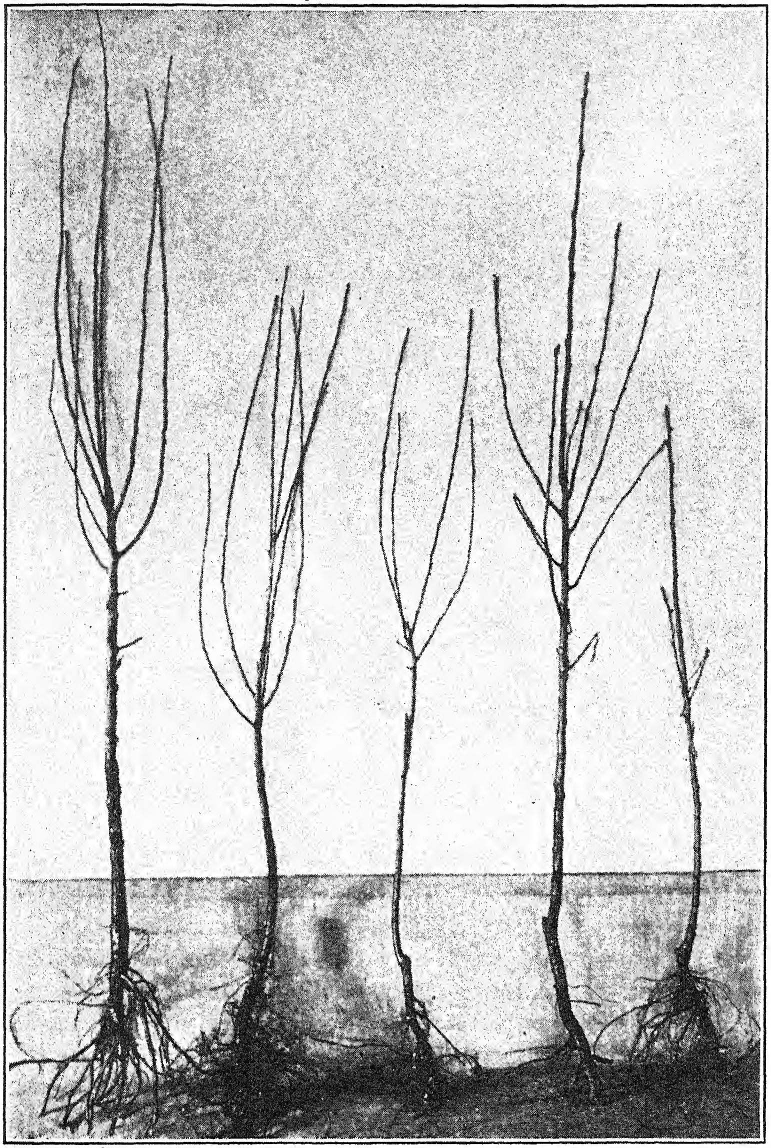


FIG. 61.—Grades of nursery stock (in 2-year-old class). From left to right the first three are Northern Spy apple, XXX, XX, X grades respectively; fourth, Keiffer pear, best grade; fifth, dwarf Duchess pear, best grade.

circumstances the only possible sources of branches are adventitious buds, which lack the uniformity of arrangement that characterizes the normal buds; as a result, the spacing and arrangement of the limbs are likely to be inferior.

From year to year, in most sections where nursery stock is grown, weather conditions so affect the size of the trees and the proportion that fall within the various size-groups, that a tree of a given size might be small for one year and medium for another. Furthermore, size is not always a safe guide. A small yearling, left undisturbed in the nursery row and cut back close to the ground, may make a vigorous growth the following year and be graded as a first-class yearling rather than an inferior 2-year-old. Sometimes "cut-back" trees of a different kind are offered. A cold winter or early occurrence of cold weather may damage trees to such an extent that they are unsafe for planting, and the nurserymen may cut them back, removing all the injured wood. Trees of this sort, aside from lacking symmetry, should prove satisfactory in the orchard. Clearly, then, few rules can be laid down as absolute; small trees may or may not be inferior and cut-back trees may or may not be inferior. The planter may insist on getting material that is above suspicion on these various counts, or he may effect some saving by using more or less material which might be open to suspicion unless offered by a nurseryman in whom he has confidence.

Sometimes the prospective peach planter is offered "June-budded" trees. These are produced in southern nurseries where the length of the growing season permits the nurseryman to plant peach pits in the winter and to bud the resulting seedlings in June of the same year. For this he either uses buds cut while the trees were dormant and kept in cold storage until they are used or he uses buds cut from the current season's growth. As soon as the buds have taken, the seedlings are cut back, and growth from the inserted bud produces a budded tree in the same season. These trees are, however, not equal in size or development to those produced by the slower, standard method and, despite their lower price, are little used by northern planters.

DWARF TREES

Dwarf fruit trees are produced by working the standard sorts of fruits on stocks which reduce the size of the trees without materially affecting the size or the quality of the fruit they produce.

The so-called Paradise apple stocks produce small apple trees whose limited growth and rather sparse foliage often result in the fruit being of particularly high color. The Doucin apple stock produces a tree intermediate in size between the "standard" tree growing on seedling roots and the type produced by the "Paradise." In Europe, dwarf pear trees produced by working the pear on the quince are in wide use, because of the ease with which they lend themselves to espalier and cordon training against walls, where the extra heat they receive is useful in attaining proper ripening of the fruit. In the United States, heat during the growing season is less often a limiting factor in pear production, and the labor and expense involved in special training is greater; consequently the dwarf tree is less important so far as quality is concerned. Control of psylla and blight in the tops would make the dwarf tree desirable were it not that the quince root is particularly susceptible to blight and to freezing, contingencies with which European growers have never or rarely to deal. The passage of time may reveal a pear-dwarfing stock other than the quince, which would change matters considerably; with the present materials, commercial orchards of dwarf pears are rarely successful in the United States. Peach trees seldom attain undesirable size on peach roots and they bear early; consequently there is no present occasion to seek special dwarfing stocks for commercial plantations of this fruit. Some plum stocks appear to have a rather dwarfing effect on peach trees, and there are some varieties of peach, which, since the dwarfing character is inherent in the variety itself, are dwarfs regardless of the stock on which they are worked. In general, dwarf trees may be said to merit no place as yet in the commercial orchards of the United States.

DOUBLE WORKING

Double-worked trees are offered by some nurseries. This term signifies that the trees have been twice grafted or budded. The purpose in this double working varies with the material. Some pear varieties, as Bartlett, for example, do not make a good union with the quince, while others unite very well. To make a satisfactory dwarf Bartlett tree, therefore, the nurseryman buds the quince root to the Hardy pear and later buds or grafts the Bartlett into the Hardy. The Bartlett unites well with the Hardy and the Hardy unites well with the quince. The Grimes

apple, notoriously subject to crown injury or collar rot, is similarly worked on a variety that is less susceptible, such as Delicious, which of course was budded or grafted on a seedling.

BUDDED OR GRAFTED TREES

Choice between budded and grafted apple trees is not particularly important in most commercial apple sections. Wherever root killing is likely to become important, however, root-grafted trees are preferable. These are generally made from a short piece of root and a rather long cion and when they are planted most of the cion is below ground. The underground portions of the cions of most varieties eventually send out roots which, because of their favorable location, are likely to become the chief roots of the tree. Varieties selected for northern regions are necessarily hardy and the cion roots appear to share in this ability to resist cold. They are, therefore, less susceptible to freezing than the average seedling roots. Distinction should be made between the process and the materials; cion roots are not inherently hardier than others, unless they come from hardier varieties, and cion roots from tender varieties would be more tender than those of the average seedling.

At one time there was much discussion concerning the supposed superiority of root-grafted trees grown from whole roots over those grown from "piece roots." Experience has shown clearly that there is no consistent difference between them.

SPORTS, STRAINS, AND "PEDIGREED" NURSERY STOCK

Over a period of many years horticulturists have noted the occasional occurrence of single branches which consistently bore fruit of a different character from the rest of the tree. These departures in type took somewhat diverse forms resulting, for example, in a peach producing a nectarine, or a Bartlett pear producing fruit with stripes, or a Baldwin apple producing a red russeted apple, or a variety characterized by red stripes producing solid red fruit. Buds or cions from these limbs reproduced the variation and in some cases the new types have received names as new varieties. Variants of this kind are known as "bud sports," or improved strains of the variety from which they have sprung.

Recognition of these "sports" has led to the supposition that sports of other sorts may arise. Particularly fruitful trees have

been sought as the source of propagating wood, on the assumption that trees raised from them would also be particularly fruitful; this is done, of course, on the assumption that these trees were fruitful because of sporting in the buds from which they were grown and in disregard of the possibility that the superior fruitfulness may have been due to their having been planted in soil that was particularly fertile or particularly well drained or their having been worked on seedling stocks that were particularly congenial or adaptable.

Actual evidence is still too meager to permit final judgment on the likelihood of permanent yield variations arising as bud sports. Experience with citrus fruits has been interpreted to show that degenerate or unfruitful strains may arise in this way and, because their great vigor makes them most likely to be chosen as the source of bud sticks for further propagation, trees from this wood may in time outnumber the fruitful strains in the orchard. Cases of actual improvement in fruitfulness are very rare and not altogether convincing. In the deciduous fruits, such evidence as is available is almost wholly against the existence of strains differing in yield within the variety. This in itself is not proof that they do not exist; it may merely reflect the difficulty of recognizing them and of distinguishing between a possible heritable fruitfulness arising from a bud variation and the transitory fruitfulness that is due to favorable environment. Distinction between these cannot be made by any other known criterion than raising and fruiting the tree, which requires a long time. Meanwhile, the grower may elect to pay more for "pedigreed" or "bud-selected" stock as insurance against a possible loss, but he should do it with the realization that the value of such stock is not established.

Recent studies have rendered possible the indentification, by their leaf characters, of some varieties in the nursery row, thus permitting the elimination of "rogues." Some nurseries are having their stock inspected, and the trees "certified" on this basis as true to name.

It should be evident that few invariable rules can be laid down for the selection or purchase of nursery stock. The fruit grower should remember, however, that the nursery catalogue is not a planting guide and that the business of the nursery salesman is that of selling trees. Not infrequently the nursery catalogue or the nursery agent recommends certain varieties or certain stocks

and often the grower does well to follow these recommendations, but sometines they are made without due consideration of local conditions of soil, climate, or market. The grower is the person who finally profits or loses by the transaction. His is the responsibility. His only insurance is his own knowledge of varieties, stocks, soils, and other environmental conditions. The nursery can, at the best, only guarantee sound disease-free nursery stock of the grade, kind, and variety ordered.

CHAPTER XIV

TRAINING THE ORCHARD TREE

"Just as the twig is bent the tree's inclined." For numerous generations many European fruit growers have exemplified this proverb by training trees into forms that to a fruit grower in the United States seem curious indeed. Some comparatively simple examples as they grew in the gardens of the National School of Horticulture at Versailles, are shown in Figure 62. The vertical flatness of the trees is not to be ascribed to the artist or the engraver; trees were and are grown in that and various similar forms. In much of the fruit-growing area of Europe most summers are so cool that the ripening of hickory nuts is rare enough to receive mention in gardening journals and the area of glass-houses devoted to grapes and peaches is not inconsiderable. Proper ripening of peaches and of many pears and apples requires all the heat and sunshine that are available in the ordinary season. The "candelabra" trees illustrated in the figure constitute an adjustment to these requirements. Grown against a wall they receive reflected heat and are kept "open" to utilize sunlight to the utmost. In some cases, too, the space saved by this training may be more important than the labor involved in developing it. Few have contended that trees of this type yield heavily; in the production of apples for cider, a specialized enterprise in Europe where cheapness, which requires high yield, is important, trees are grown in the familiar orchard form.

In the United States, summer heat and sunshine are comparatively abundant and color and quality develop almost automatically. Labor is more expensive than space and the determining factor in profit is yield. Single apple trees have yielded over two tons of fruit in one season. Consequently the American orchardist quite rightly gives his trees more room and inclines the young twigs in other directions or lets them incline themselves.

Left to itself, an apple or a pear tree tends to grow tall and rather slender, with a single trunk extending undivided to the

top and numerous comparatively small branches radiating from it. Since the branches are small no one of them bears a heavy load and splitting of the crotches is rare, but the very persistence of the numerous branches makes the tree rather compact, the

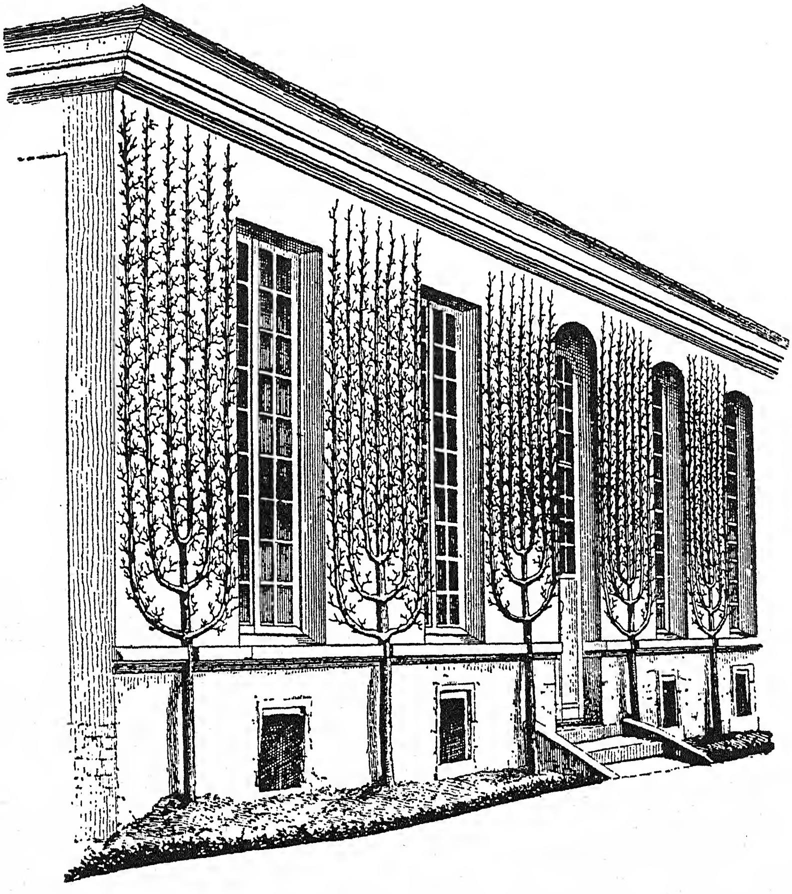


FIG. 62.—"Candelabra" training of pear trees. (*After Robinson*, 1876.)

foliage dense, much of the fruit poorly colored, and renders spraying, thinning, and picking difficult. This was the prevailing type of tree in the early orchards of this country, when apples were raised largely for home use in cider, as dried fruit, for cooking, and as stock feed; markets were small and no pro-

nounced color preference existed. For the prevailing conditions, then, this naturally growing tree served its purpose well and it lived a long time.

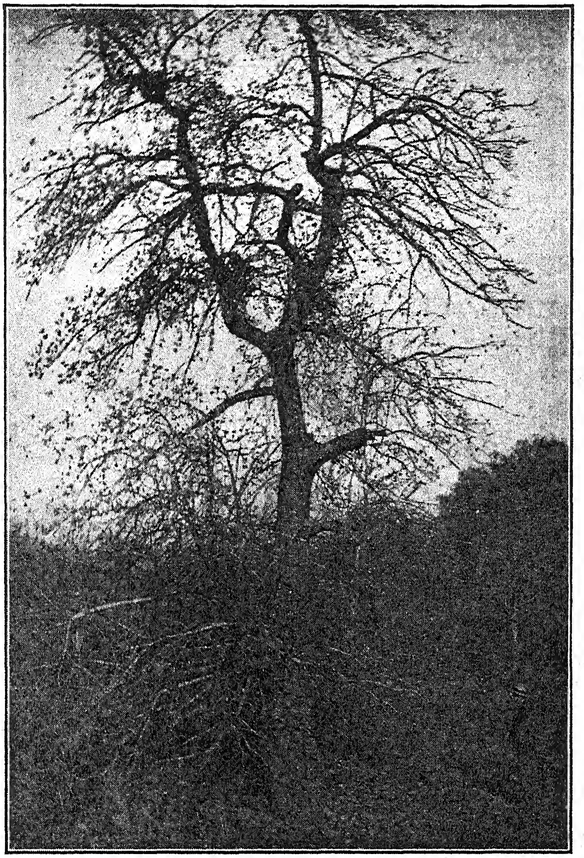


FIG. 63.—A "natural" type, *i.e.*, an unpruned, apple (Cannon Pearmain) tree, 70 to 75 years old, in a Virginia orchard. It still bears heavy crops.

THE CENTRAL-LEADER TYPES

Between the naturally growing tree (Fig. 63), the central leader (Fig. 64), and the pyramidal tree (Fig. 65) the only differences are in refinement of detail. In the unpruned tree the successively formed upper limbs tend constantly to assume dominance over the lower, gradually shading out the lowest limbs, making the tree ultimately more or less umbrella shaped

and its fruiting region high. With these tendencies corrected, the natural tree becomes a central-leader tree; this effect is secured principally by continued heading back of the central leader and the upper limbs and may be accompanied by some

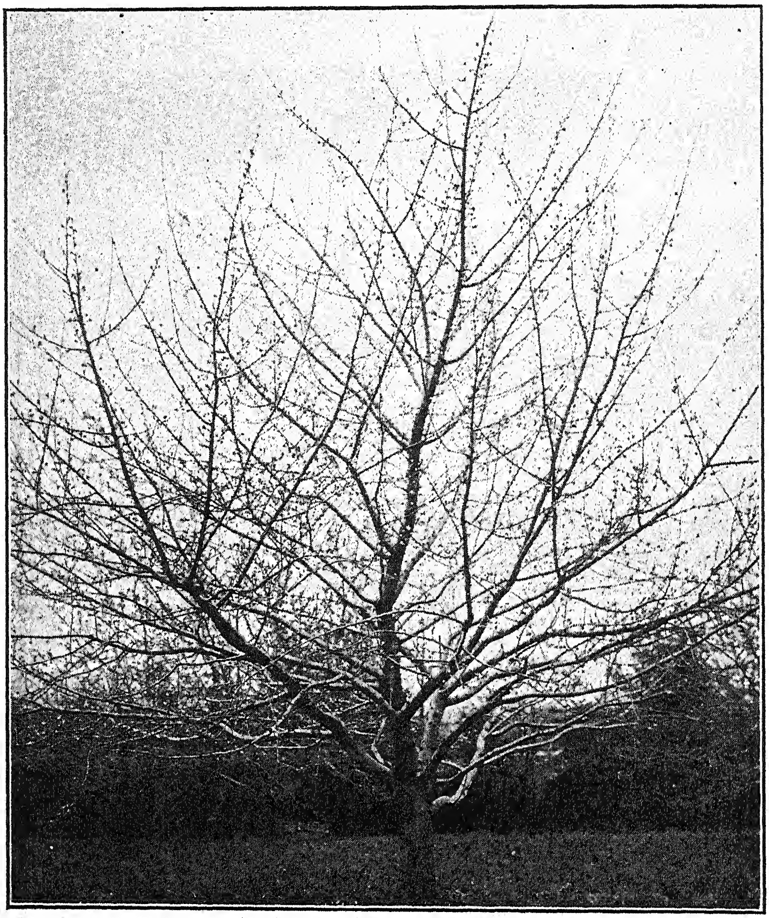


Fig. 64.—An 18-year-old leader type McIntosh apple tree. In spite of the leader training and the large number of scaffold limbs, it has been kept reasonably open by light pruning (compare with Fig. 69).

thinning of the lower limbs. The pyramidal tree differs from the central leader only in the greater care given to these details and in having the limbs start practically at the surface of the ground. Ordinarily it is a smaller tree than the central leader;

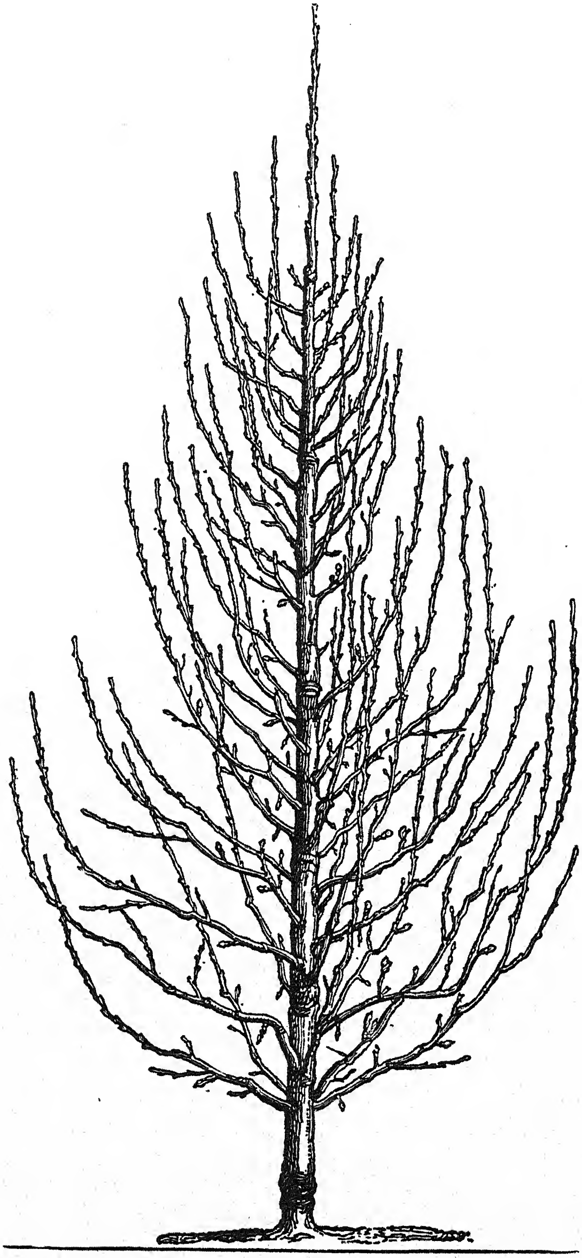


FIG. 65.—A typical pyramidal pear tree, 6 years old. (*After Hardy*, 1870.)

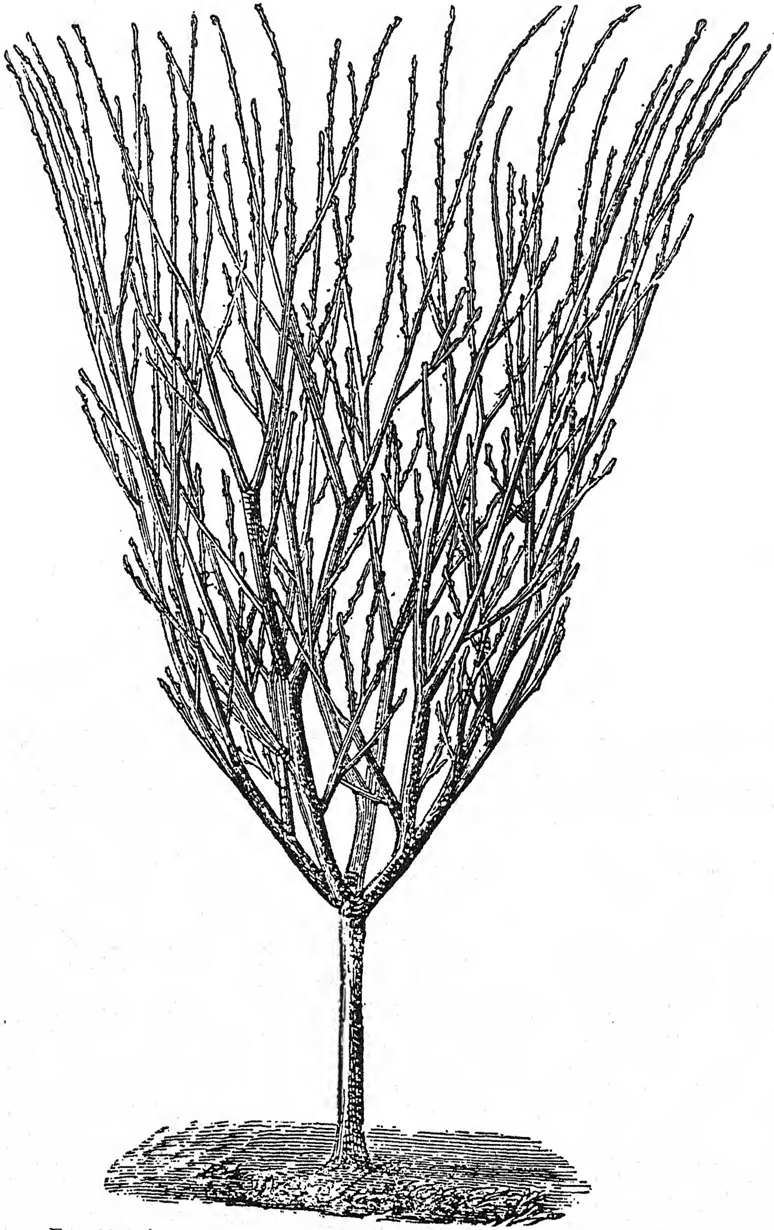


Fig. 66.—A vase-shaped peach tree, the ideal of 1851. (*After Barry.*)

indeed, this style has been used extensively with dwarf trees. Fundamentally, however, central-leader and pyramidal trees retain the multiplicity of limbs characteristic of the natural type and with it the tendency to its disadvantages.

THE OPEN-CENTERED OR VASE-SHAPED TREE

With the development of markets and the rise of commercial orcharding came a premium on well-colored fruit. Before very long the keener orchardists were growing, along with new varie-

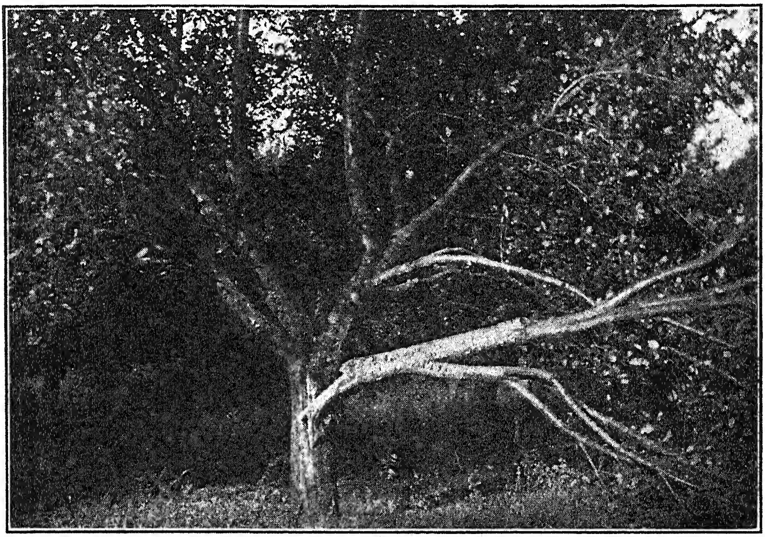


FIG. 67.—The result of training to the open-center type and permitting all the scaffold limbs to originate at practically one point on the trunk.

ties, a new type of tree, calculated to meet the new requirements. This was the vase- or goblet-shaped, now known commonly as the open-center, tree. Figure 66, of French origin, published in *Barry's Fruit Garden* in 1851, illustrates the ideal then prevalent. The chief consideration in developing these open-center trees was the exposure of the fruit to sunlight; to that end the centers were rigorously cut out, leaving a large open space. The fruiting area was essentially an inverted hollow cone. With slight modifications, this type persisted as the ideal of ambitious apple growers until most of the trees now bearing had made considerable growth and it is by no means unknown in young orchards of the present. In the peach it is still the standard.

As these open-center trees grew older, however, they became less and less satisfactory. The division of the trunks into three or four scaffold limbs placed immense loads on each limb; if a greater number of limbs were developed to divide the load, their

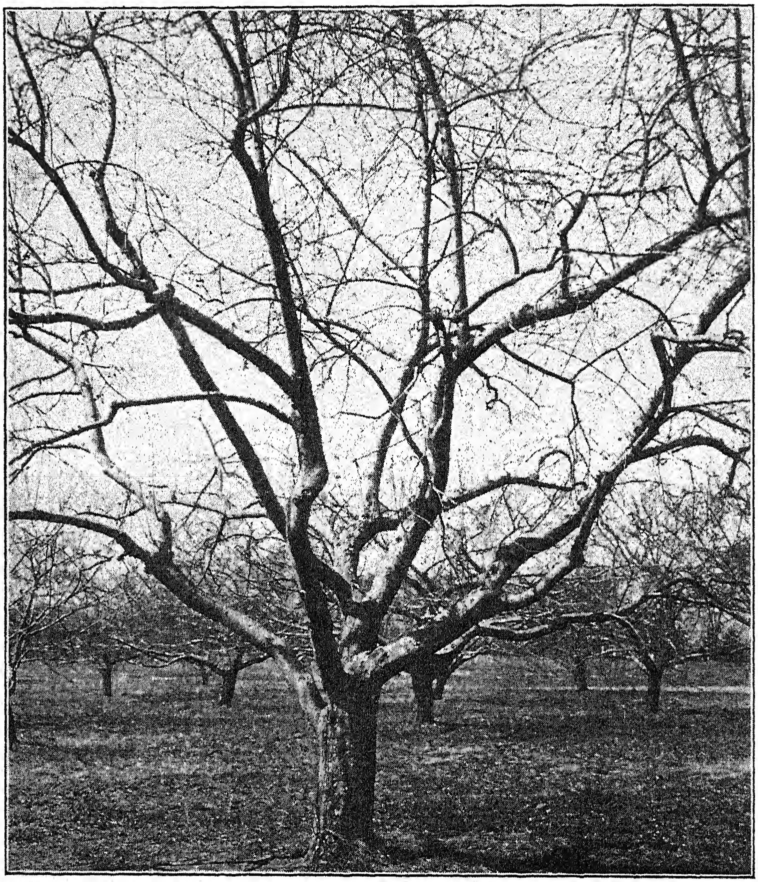


Fig. 68.—A tree that was trained to the modified-leader type, with reasonably wide spacing of the scaffold limbs and the resulting mechanical strength of the crotches and framework. The tree has a reasonably open non-bushy center.

bases crowded one another on the trunk as they grew older. In either case, the attachments of the limbs to the trunk, called the "crotches," were weak and the limbs, or even the trees, split down; Figure 67 depicts a tree which illustrates these two weaknesses in framework building. Furthermore, with great

perverseness these trees sent out water sprouts to fill the open center. When these were removed the sun shone not only on the fruit but also on the bark, often with dire consequences in the form of sunscald, and ultimate rot and breaking. In peaches, which do not develop the stature of the apple tree, the strain on the crotches is not as great, but limb splitting is nevertheless

Fig. 69.—An 18-year-old, open-center McIntosh apple tree. In spite of training to an open center it is thick and bushy because of lack of proper thinning out during the last few years (compare with Fig. 64).

a constant occurrence. Regardless of kind, open-center trees are usually short lived.

THE MODIFIED-LEADER TREE

Dissatisfaction with both the open-center and the central-leader tree, particularly with the open-center tree, led to the development of a compromise between the two. This type is called the "modified leader" (Fig. 68). The tree is grown as a

central-leader tree until it attains a height of 5 to 8 feet; from this stage it is handled as an open-center tree. The term "delayed-open-center," sometimes applied to it, describes its appearance and explains its development. The greater length of the trunk permits the development of a rather large number of scaffold limbs and at the same time avoids crowding of their bases. In this way the crotches are simultaneously made

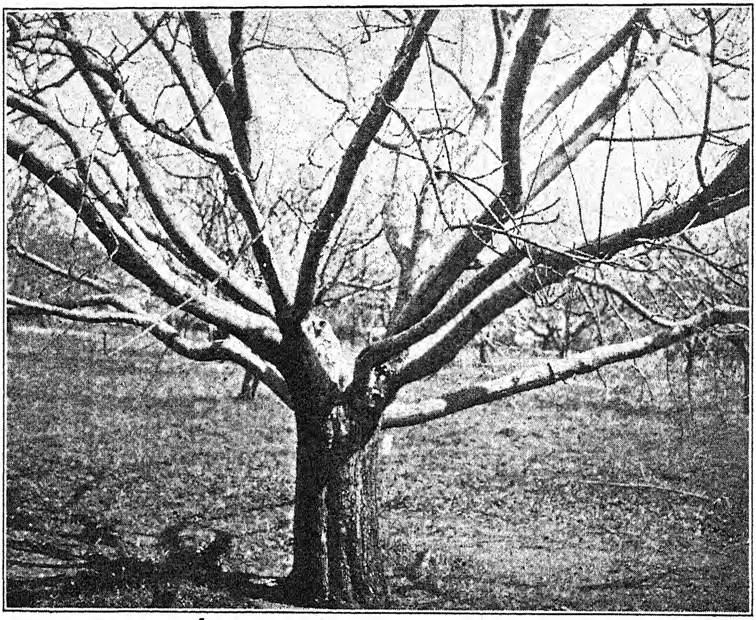


FIG. 70.—An open-center Red Astrachan apple tree with a large number of scaffold limbs. Comparatively few varieties form as good crotches and as strong frameworks when the limbs are so closely spaced.

stronger and given lighter loads, with little sacrifice of the advantage inherent in the open-center tree.

Adherence to any type of training does not automatically realize its advantages or imply full acceptance of its weaknesses. Pruning, which is distinct from training in its purpose, though it is done with the same tools, and occasionally is simultaneous with it, ultimately governs the density of the top more than training. Careful pruning can make a central-leader tree open enough to meet any reasonable standard (Fig. 64), and lack of pruning permits an open-center tree to become very dense (Fig. 69). Some open-center trees have strong crotches, partic-

ularly in those varieties in which the limbs make wide angles with the trunk (Fig. 70), and weak crotches may develop in central-leader trees, particularly in those varieties in which the limbs leave the trunk at very sharp angles. With average

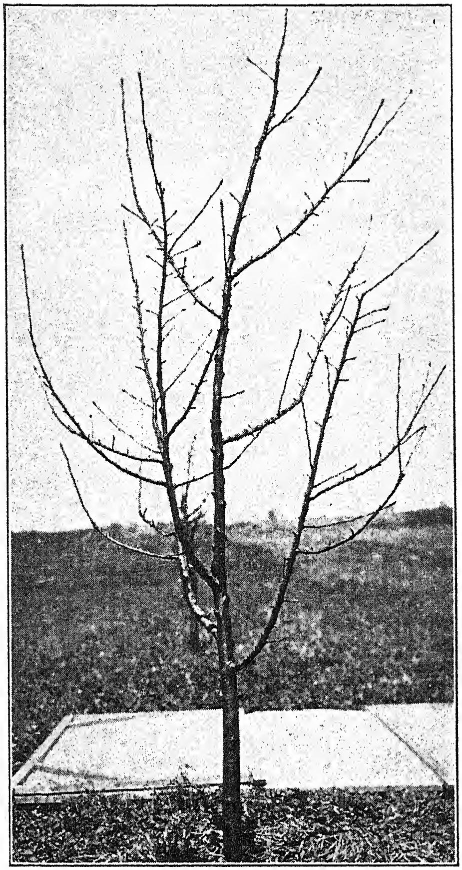


Fig. 71.—A modified leader tree "in the making." Wide spacing of the limbs gives the tree a "lanky" appearance at this stage, but it is the only way that good crotches and a strong framework can be assured.

varieties under average treatment, however, adoption of a given style of training establishes tendencies in definite directions; these should be considered when training is started and remembered as the tree develops. There is nothing to gain, for example, and much to lose in training a Rhode Island Greening to an

open center. On the other hand, the orchardist handling mature Clairgeau pear trees trained to a central leader should watch the density of the top very carefully. In the first case color is not desirable; in the second it is.

TRAINING PRIMARILY A MATTER OF SELECTING AND SPACING SCAFFOLD LIMBS

The principal difference between the open-center, leader, and modified-leader trees consists in the number, spacing, and

FIG. 72.—A leader tree (or at least a long-delayed modified leader), 85 years old, mechanically strong and apparently good for another 85 years. The wide spacing of the branches has made possible strong crotches.

arrangement of scaffold branches. Resulting "style" or form is more or less incidental. If this conception is kept in mind during the actual training, better formed, though perhaps less distinctively styled, trees will be secured. The young tree shown in Figure 71 looks ungainly, almost "lanky." In 20 or 30 years, however, when it is in full bearing, its scaffold limbs will still be spaced some distance apart; each will have made a

"shoulder" with the main trunk, and the chance of their splitting down will have been diminished permanently. Figure 72 shows a tree that was trained in this way when young. Though perhaps a little difficult to classify as to style or type, it is practically without weak crotches and it is structurally strong enough to hold any probable load and withstand any storm. Inability

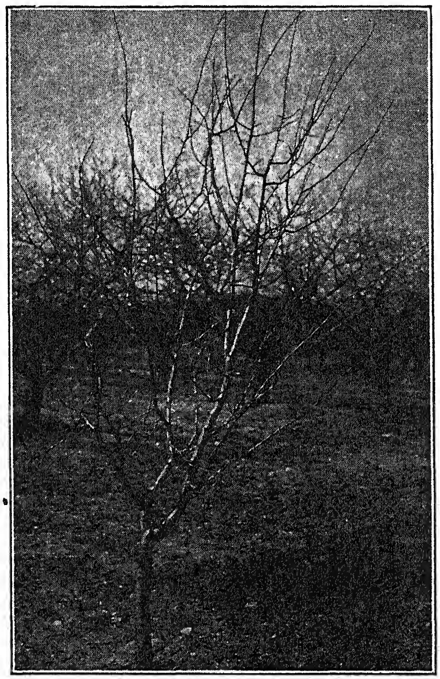


FIG. 73.—In this tree the lowest scaffold limb has been allowed to "outgrow" the rest of the tree and dwarf it somewhat. The result is a one-sided tree. This could have been prevented by heavier pruning of this lower limb and perhaps relatively lighter pruning of the other limbs, during the first few years.

to visualize a tree started with close-spaced limbs as it will appear 20 or 30 years later has contributed to most of the mistakes made in tree training.

SUBORDINATING LIMBS OR PARTS OF TREES

Two precepts are fundamental to all tree training, so far as training is done by cutting. One is that, of two branches, other things being equal, the more vigorous growth is made by the

one approaching more closely the vertical position. This should be remembered in the selection of leader and laterals.

The second, and more frequently used, precept is this: When one of two limbs is to be subordinated to the other, it should be cut back more heavily. If heavy cutting is practised throughout the tree, the response is vigorous growth in all limbs, but particularly heavy cutting of one branch appears, in the language of the older gardeners, to "reduce its pull for sap;" it certainly reduces its growth.

Cases of one branch outgrowing the others are not at all uncommon. Uncorrected, this condition in young trees may lead to the development of a lopsided tree (Fig. 73); severe

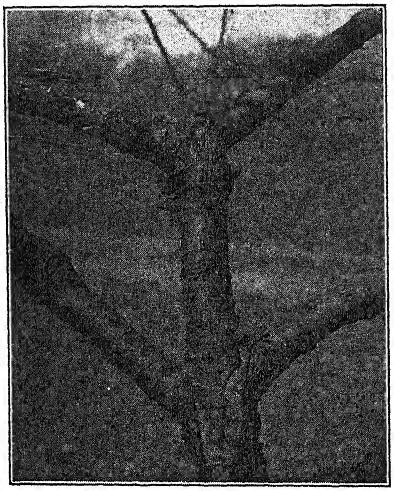


Fig. 74.—The result of pruning two limbs equally so that neither is subordinate to the other.

pruning restrains the unduly ambitious, and light pruning—or none—permits the laggard branches to resume their proper rank.

Sometimes two or more unrestrained laterals, originating near one level on the trunk, suppress the leader (Fig. 80). In extreme cases the leader dies, leaving an open-center tree with a wound in the center inviting fungus invasion. This is evidently what is destined to occur in the tree shown in Figure 80.

"Forks" constitute another structural weakness which can be prevented or remedied by proper cutting. Very frequently growth from a lateral bud near the tip produces a shoot which

makes growth equal to that of the terminal shoot, the two forming a fork. As these shoots increase in diameter, new wood is laid down equally by each, and there is very little overlapping of fibres from one to the other; the consequence is a structurally weak crotch. If the interior angle of the crotch is very sharp, such new wood as is laid down on the inside tends to act as a wedge, enhancing the weakness. These forks, wide or narrow, are likely to split under the strain of a heavy load of fruit or of a heavy coating of ice (Fig. 74). If, however, one arm of the fork makes greater growth than the other, its new wood overlaps that of the smaller arm, anchoring it in more firmly, and the strain on the smaller is, of course, less. The subordination of

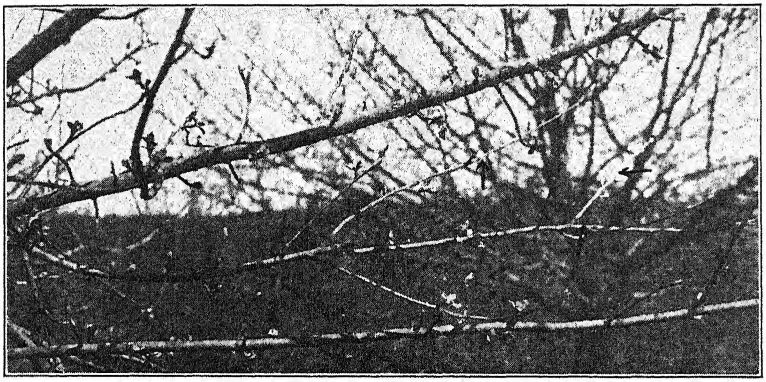


Fig. 75.—A small, interior fruiting limb. Instead of pruning out these limbs it is ordinarily better practice to subordinate them by cutting them back into 2- or 3-year-old wood (indicated by the arrows).

one arm may be secured by pruning it more heavily than the other and the difficulty may thus be avoided. A still surer preventive is the complete removal of one arm, if it can be spared.

Another type of subordination is illustrated by the treatment of a small branch arising in the interior of a bearing tree (Fig. 75). It is well supplied with fruit spurs and capable of bearing several good fruits annually and is to that extent valuable; unrestrained, however, it grows enough to interfere with other limbs and its loss as a producing unit in the tree can be delayed only for a few seasons. On the other hand, if it is cut back into 2- or 3-year-old wood, (as indicated by the arrow in the figure), its growth is checked and it may be retained for many years as a small, subordinate fruiting branch. The removal of large

numbers of these interior fruiting limbs, which really should be only subordinated, leads to the production of many water sprouts or "suckers" that must be pruned out later; it increases the danger from sunscald and last, but not least, on young trees it delays the attainment of bearing condition.

FIG. 76.—A tree that has been severely "dehorned" to reduce the height of its top. Figure 77 shows the characteristic response to this type of pruning. Figure 78 illustrates a better way of lowering the height of very tall trees.

LOWERING OR RAISING THE TOPS OF TREES

In time, orchard trees of many kinds become so tall that the necessary care and harvesting of the fruit in their upper limbs becomes unduly costly. Many orchardists believe that growing fruit more than 22 or 23 feet above ground is unprofitable. Furthermore, the growth of the very high branches is likely to affect adversely the yield and grade of fruit produced by the lower parts of the tree. Consequently, the lowering of the tops of trees ("dehorning") is a rather frequently recurring operation in many old orchards (Fig. 76). Besides removing most of the bearing wood of the trees and thus greatly reducing yields for at least several years, it induces the production of large numbers of water sprouts (Fig. 77). These crowd close together, require much thinning out, and are slow in becoming fruitful. By the time they are well into bearing and the tree is again approaching a normal yield, it is almost as tall as it was before dehorning and before long another reduction in height becomes

necessary. A much better way of reducing the height consists in cutting back the tallest limbs at a point just above a lateral branch (Fig. 78). Considerable fruiting wood has been left and yields are reduced much less than they are by dehorning. More important: fewer water sprouts follow this kind of pruning and

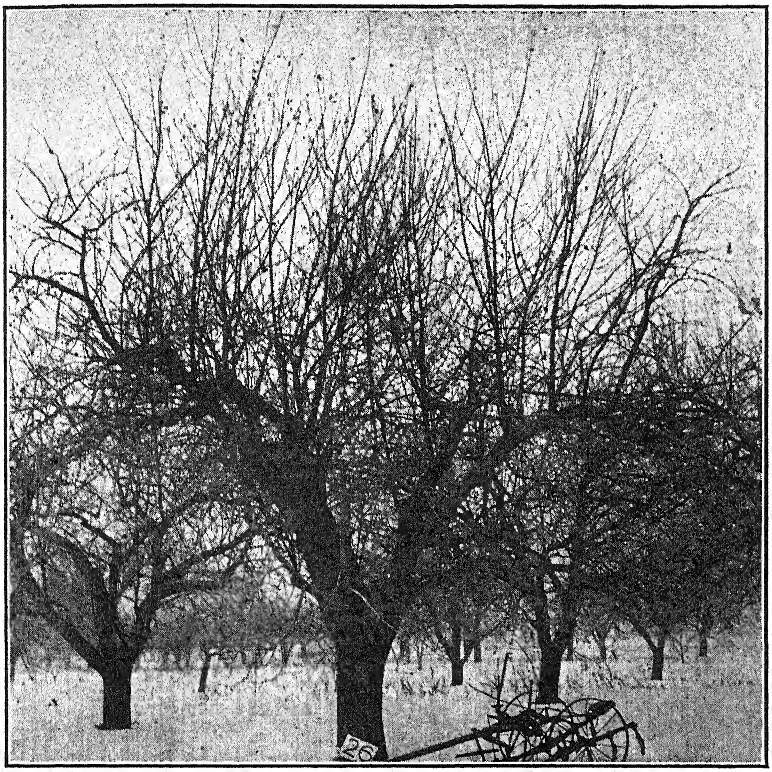


FIG. 77.—An old apple tree that shows the characteristic response to dehorning such as that illustrated in Fig. 76.

a longer time elapses before another lowering in height becomes necessary.

Branches which have become so long or drooped so low that they interfere with cultivation or with other operations in the orchard may be treated in a similar way, except that in this case the cutting takes the branch back to an upright lateral.

THE FUNCTION OF TRAINING

If training of trees is considered as a means of attaining two chief objects—namely, promoting certain tree functions and facilitating certain orchard operations—the importance of the the process appears more nearly in its proper perspective and at the same time failures due to entirely different causes will not be attributed to mistakes in training. Outside of the gain in earliness of maturity and in flavor, important in some parts of Europe but not ordinarily in America, secured by training trees in espalier or cordons, the tree function principally influenced by training is the coloring of fruit incident to the admission of more

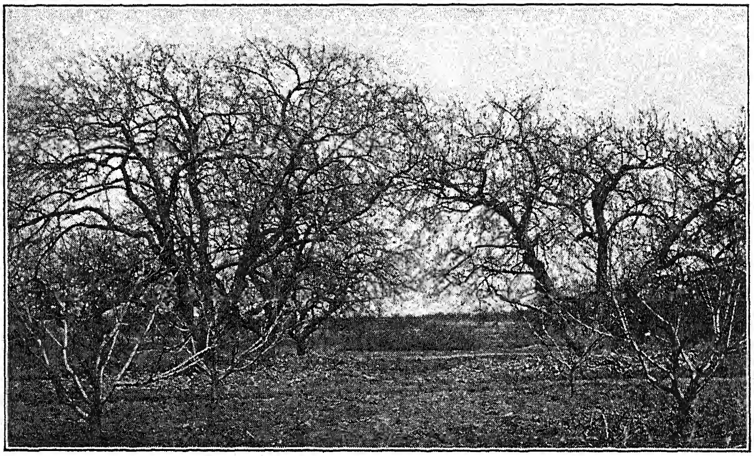


Fig. 78.—In the background two old Golden Russet apple trees; the top of the tree at the right was lowered by judicious cutting back to strong lateral branches. This pruning is not attended by the effects following dehorning, illustrated in Fig. 77.

sunlight to the interior of the tree. With red varieties of apples and with peaches this is of some importance; with other varieties of the apple and with other kinds of fruits it is not. The relative importance of this effect of training, which more than anything else led to the once all-but-universal adoption of the open-center style, has probably been overemphasized. How training, if well done, will facilitate operations such as cultivation, spraying, thinning, and harvesting, is almost self-evident. Indeed, under most conditions and with most fruits this is by far the most important thing that it accomplishes. To the extent that it

really facilitates these operations it reduces production costs and it is in this way that its effectiveness and value should be measured. However, the reduction in yield that sometimes occurs incident to training, especially when the objectives attainable by training are not kept clearly in view, may occasion greater loss than the gain from reduced acreage production costs and improved fruit color.

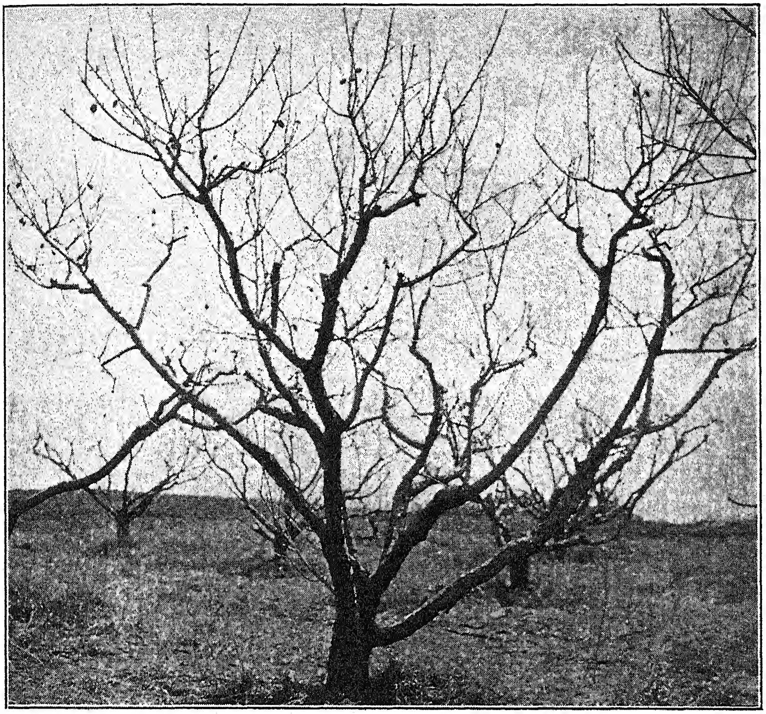


FIG. 79.—A 31-year-old peach tree that is still strong and vigorous and apparently good for many more years of production. Though it is an open-center tree, its scaffold limbs were wide spaced, like those in Fig. 71, with the resultant formation of strong crotches and a strong framework. Consistent leading back of the branches has kept the top compact and reduced the strain of heavy crops on the crotches.

THE DANGER IN TRAINING

Bad training is likely to do more harm than none at all; trees can be literally trained to early death. Left to themselves, they neither develop quite the sturdiness that is imparted by judicious training, nor do they, on the other hand, intensify their weakness

as improper training frequently does. If there is any value in cultivation, orchard trees are called on to sustain greater loads

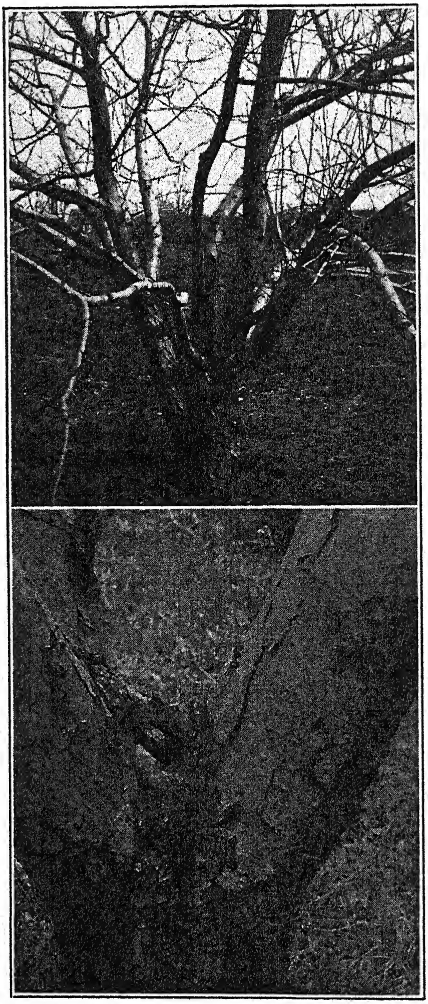


FIG. 80.—*Above*, A leader tree in which the leader is being girdled or choked out by the more rapid growth of the side limbs. This could have been prevented, if, years ago, the side limbs had been subordinated by relatively heavier pruning. *Below*, The aftermath of a similar case.

than wild trees and the crotches and branches should be adequate to withstand severe strains. In the face of this fact, many fruit growers have sacrificed structural sturdiness of the tree in favor

of increased color of the fruit. This course is comparable to killing the goose that laid the golden eggs, but, because the consequences are not immediately obvious, many growers cultivate half trees, or even watch their orchards fall to pieces, with many pangs of regret but no qualm of conscience.

Good training increases longevity. Figure 72 shows an apple tree 85 years old, well trained and "sound as a dollar," with every prospect of being good for another 85 years. Figure 79 depicts

FIG. 81.—Living cross-braces made by twisting together limbs or shoots growing from opposite main limbs may prevent splitting at the crotch and correct mistakes made early in training. Graft unions are formed between the twisted branches in the course of time.

a peach tree 35 years old, It is one of 400 similar trees in a Michigan orchard. Strong, vigorous, healthy, it appears to be equal to another third of a century of usefulness. It has already outlasted three generations of ordinary peach trees of the same variety grown on the same type of soil in an equally good environment, partly because from the beginning it was trained for structural strength.

Even when a tree has been irrevocably committed to a weak framework, all is not necessarily lost. Small branches from adjacent limbs may be braided together and allowed to unite by

natural grafting, thus forming "live braces" (Fig. 81). In time these become very sturdy.

Training is a means and not an end. What John Lindley said in 1855, though written primarily of espalier training, will undoubtedly have more or less applicability to a wider field until the millenium:

In matters horticultural there are martinets as well as in matters military; and many a gardener practically falls into the error of supposing that the goose-step, a tight jacket, leather stock, and pipe clay make the soldier. He measures the angles of a tree, pinions its limbs, drills its branches by inexorable rules, "cuts hard in," "lays in close," and then believes he has exhausted skill. The tree looks well perhaps, but a small matter makes it ill, limb after limb dies away, fruit does not set, and all its spruceness ends in rags and tatters. This comes of neglect of first principles . . . It is because it is observed without intelligence, and without a thought to first principles, that mere routine, however excellent, is apt to lead to failure. And it may be asserted with perfect truth that in training fruit trees, it is better to understand principles and to be ignorant of rules of practice, than to be familiar with the latter and unacquainted with the former.

CHAPTER XV

PRUNING THE BEARING TREE

LaQuintinye, the great French gardener, said, more than two centuries ago, "Everybody cuts, but few prune." In the succeeding years, variety lists have been remade time and again, vast fruit industries have risen in lands then wild, a whole program of pest control has been erected, and many cultural practices have become more or less standardized, but his statement has as much applicability as it had when Louis XIV pruned peach trees at Versailles. No cultural detail in American fruit growing is so diverse in conception and so varied in execution, from year to year, from orchard to orchard, and from section to section, as pruning. The expectations of what it is to accomplish and of the ways in which it is to bring these things about are often indefinite if not contradictory, and in many orchards branches are slashed from a sense of duty, like an ancient sacrificial offering, rather than with any clear purpose.

To assume that all trees need pruning is about as baseless as to assume that all men need spectacles. LaQuintinye himself and many other leading European exponents of the art expressly disclaimed any need of pruning standard trees grown as they are grown in America; nevertheless generation after generation has attempted to apply maxims derived from European experience with dwarf trees trained against walls to American orchards of standard trees grown in the open. Accurate quantitative measurement of effects on a comparative basis has been difficult and only in very recent times has actual evidence begun to displace opinion; in fact, work of this kind is barely under way and many of the established practices have not yet undergone the close analysis of costs and returns.

PRUNING HAS A DWARFING INFLUENCE ON THE TREE

All pruning involves the removal of more or less wood and of a larger or smaller number of buds; it also removes potential leaves and, often, potential fruits. An assumption has prevailed that

this reduction in number of buds diminishes the number of points where nutrients are required and thereby increases the supply for each remaining bud. This is, in general, true so far as water, nitrogen, and the mineral elements are concerned; of these the tree is wholly a consumer and the amounts removed and lost in ordinary pruning are generally slight compared with the economy effected. Carbohydrates, however, are manufactured as well as consumed by the tree and pruning affects their manufacture as well as their consumption. Aside from the loss of stored carbohydrates always incident to the removal of wood, the removal of leaf buds cuts down future production at the same time that vigorous growth in the remaining shoots consumes carbohydrates and prevents their accumulation. This, in turn, may slacken the growth of the roots, resulting finally in a check to the vegetative growth of the whole tree which may be, despite its temporary vigorous growth, actually smaller than it would have been without pruning. Since vegetative vigor and subsequent fruitfulness are often closely related, the new wood may be temporarily more fruitful than the older wood it replaces, and under some conditions an old tree treated this way may bear more heavily or more regularly than it did preceding the pruning or than it would have borne without the pruning. In fruits of growing habits like that of the apple, this effect might not be evident until 2 or 3 years after the treatment.

PRUNING BEARING TREES USUALLY THINS THE CROP

Under some circumstances pruning may remove many fruit buds. If these are present in great numbers the effect may be, in no small degree, comparable to a thinning of the fruit. This pruning reduces the number of points where more carbohydrate is consumed than manufactured and to this extent may conserve the supply or at least prevent its utter depletion by an excessive crop. In any case, the remaining points of consumption have each a larger supply of carbohydrates available for vegetative growth and for the development of fruit which may become larger and sometimes of better color or better quality. This is essentially the type of pruning commonly given the grape, the raspberry, the blackberry, and mature apricot and peach trees. To the extent that the increased size and quality of the fruit compensate in volume and price for the diminished number this pruning is profitable. It has, of course, other effects which,

though less immediate, are none the less important. By preventing overbearing and by local stimulation, it generally makes the growth of new wood, which is to bear the crop next year, more vigorous and potentially more fruitful.

The peach tree shown in Fig. 82 was 8 years old at the time the photograph was taken. It was growing in a good soil for peaches and had received good commercial care; the soil had been cultivated each year and two or three times fertilizers had been applied. The tree itself had been regularly pruned and sprayed. In

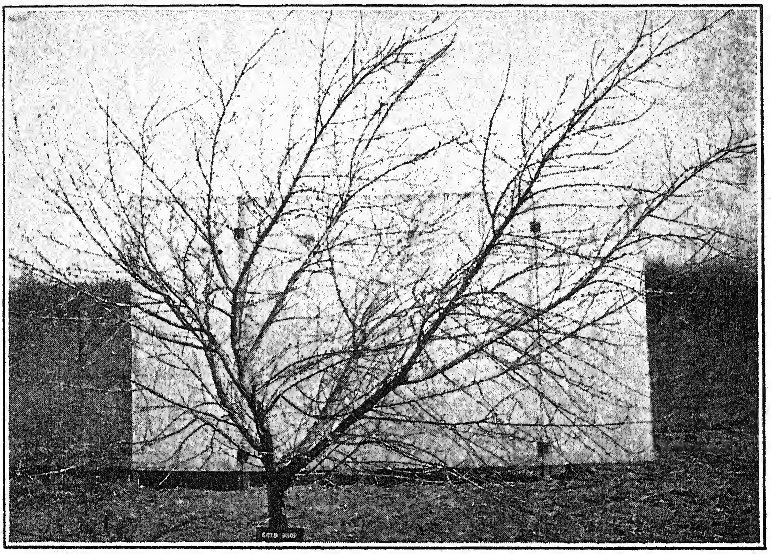


FIG. 82.—An unpruned 8-year-old peach tree with 37,582 fruit buds on its 1,526 feet of shoot growth.

brief, it was healthy and moderately vigorous; it was probably a better tree than the average for its age and kind. Actual count showed that this tree had 37,582 fruit buds distributed more or less evenly on the 1,526 feet of last season's shoots. It is, of course, almost inconceivable that any peach tree should in one season produce 37,000 peaches; indeed that number of fine, large fruits would be a fair yield for an acre. Many factors operate to reduce greatly the number of fruits that a tree actually matures, below that which theoretically is provided for by its fruit buds. Seldom do all the buds on a tree survive the winter, even in mild climates. This reduction is more important with some varieties

and in some seasons than in others. In this particular case, bud killing amounted to approximately 30 per cent. The tree when photographed, just before blossoming, therefore, possessed only about 26,000 live fruit buds. However, it is rare for every blossom to "set." In this peach variety, even under the best conditions, only about a third of the blossoms ever mature fruit. At this rate this tree would have borne more than 8,600 fruits. The proportion of blossoms that set is often much smaller than one out of three (in this particular tree it was one in five); insects and fungi

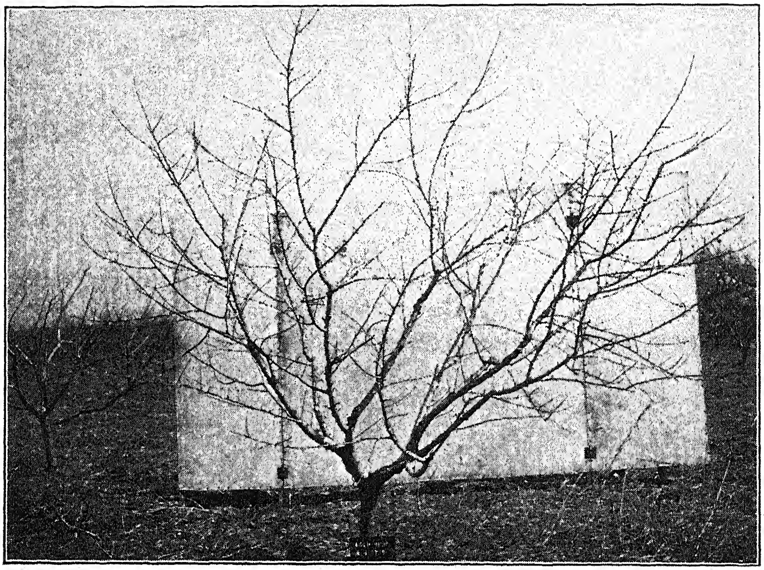


FIG. 83.—A pruned 8-year-old peach tree. The pruning removed 25,467 fruit buds; 13,387 remained.

are certain to attack some and cause them to drop and there are other sources of loss. The number of fruits actually maturing is generally far below the number theoretically possible. This tree did actually mature 1,213 fruits, however, that averaged slightly under 2 inches in diameter, and slightly over 2 ounces in weight, and numbered about 275 to the bushel. The total yield of the tree was 4½ bushels, and at prices prevailing when the crop was marketed it was worth $2.93, or $235 per acre.

Figure 83 shows, after it was pruned, a tree of the same age and variety as that depicted in Fig. 82 and located less than 100 feet from it. This treatment consisted in the removal of many

shoots and shoot-bearing branches and in a moderately heavy heading back of some of the remaining shoots; it resembled that practised by many growers, though perhaps a little more severe and more detailed than many would approve. Actual count

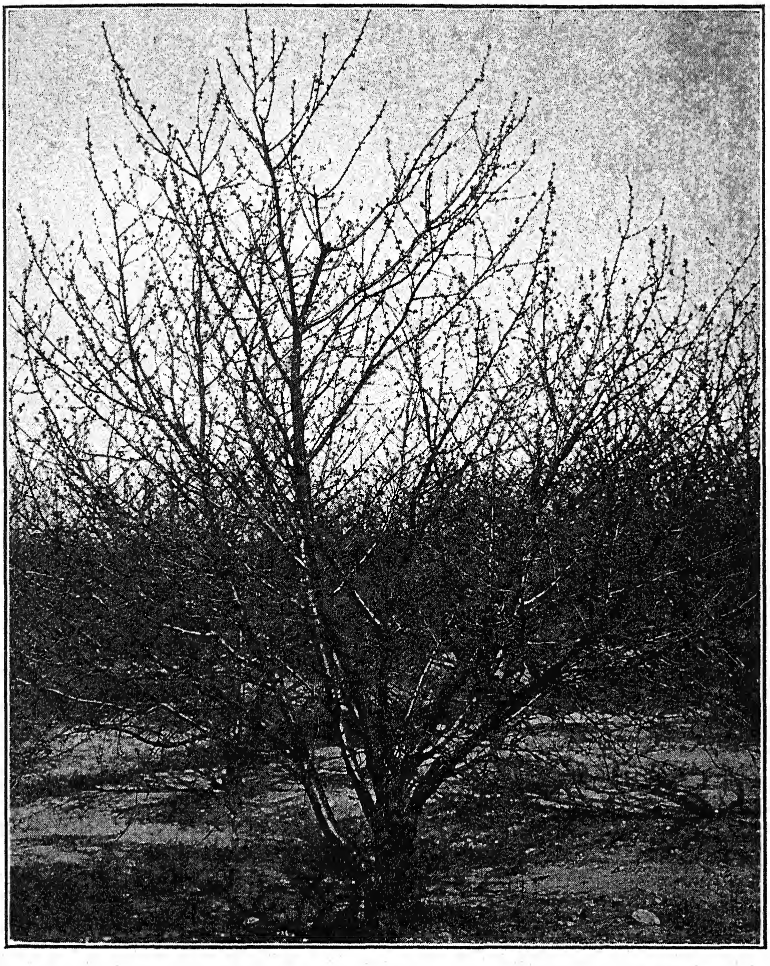


FIG. 84.—A Montmorency cherry tree unpruned for several years.

of the fruit buds on the prunings showed that a total of 25,467 had been removed, leaving 13,287 on the tree. About one-sixth of that number, or 1,350, "set." Accidents (wind, insect attack, etc.) removed many of these; 785 peaches actually matured.

These averaged about 2¾ inches in diameter; they weighed nearly 5 ounces each, and numbered about 160 to the bushel. The total yield of this tree was 4½ bushels, practically identical with that of the unpruned tree, but the crop of this tree was worth $4.50, or $360 per acre.

The general effect of the pruning was to reduce the number of fruits by a third, increase their size by an equal amount, and leave total yield per tree and acre about the same. In other words, what pruning actually effected was a thinning of the crop and a corresponding improvement in grade. This was done at a total cost of an hour's labor per tree and resulted in an increased return of $1.57 and a net profit of $1.17 per tree.

Bearing fruit plants of many kinds other than the peach regularly produce a great surplus of fruit buds. Among these are the apricot, plum, grape, gooseberry, and currant, the bramble fruits, and, to some extent, the apple and pear. With them, as with the peach, thinning of the crop is often essential to the production of fruits of large size. In most cases this is most readily done by means of the pruning shears or pruning saw before the blossoms open. Indeed, this is the principal effect of pruning in these plants.

A typical well grown 10-year-old Montmorency cherry tree is depicted in Fig. 84. It had received very little pruning for several years. Figure 85 shows another tree of the same variety and same age growing beside that shown in Fig. 84; it had received exactly the same treatment and care from the start except that before the photograph was taken it was lightly pruned. As shown by the illustrations, the pruning consisted in the removal of some of the branches in the thicker and "brushier" parts of the tree: in short, a typical thinning out. It was not a heavy pruning—not nearly as severe as that of the peach trees just discussed and far less severe than that practised by many cherry growers. A group of unpruned trees like that shown in the photograph averaged per tree 117 pounds of fruit, of which 117 made a pound, while a similar group of pruned trees averaged 98 pounds each, requiring 120 to the pound. In this case pruning produced a distinct reduction in yield without a compensating increase in size of fruit and with no other distinct or recognizable improvement in grade or "quality." Had the pruning been much more severe there might have been an attendant increase in size of fruit, but the accompanying reduction in numbers would

have resulted in a great decrease in total yield. Plainly, pruning, as done, did not pay. It did more harm than good and had it been heavier the losses would have been greater.

In explanation, it may be said that any increase in size of fruit which follows moderate fruit thinning in the cherry is so small

Fig. 85.—A Montmorency cherry tree just after a light thinning out.

as to be negligible. It reduces the crop and from that standpoint, at least, is undesirable. Any pruning which would result in an equal amount of fruit thinning is therefore equally ineffective. In the cherry, proper coloration does not depend on full

sunlight reaching the fruit, and no great difficulties are encountered in so coating the developing fruits and leaves of unpruned trees with spray materials that insects and fungi are kept under control. For these reasons, any attempt to improve grade in cherries by pruning with a view to these effects, which are frequently cited as objectives in this practice, is not likely to prove practicable.

THE INFLUENCE OF PRUNING ON QUALITY

Associated with differences in the size of fruits and sometimes with the size of the crop that the plant bears are occasional differ-

Fig. 86.—A Campbell Early grape vine pruned to 40 buds and trained according to the two-wire Kniffin system.

ences in flavor or quality. This is especially true with grapes. Figure 86 shows a vigorous Campbell Early vine pruned to 40 buds. In the September following it yielded 16.9 pounds of fruit, the juice of which tested 15.4 per cent sugar. A neighboring vine of the same variety, comparable in every way but pruned to 60 buds, yielded 22.5 pounds of fruit, whose juice tested 12.5 per cent sugar. In this case the heavier pruning resulted in a lower yield but a very distinct improvement in quality. There is, however, a limit to the possibilities of pruning in this respect. Another vine pruned to 30 buds yielded only 10.6 pounds of fruit that averaged no higher in sugar than the product of the 40-bud

vine. This overpruning, like the proper pruning, had reduced yield but had resulted in no compensating improvement in quality. With most other fruits differences in flavor and composition due to pruning are less striking, though doubtless careful investigation would show that they exist.

SOME FRUITS, AS THE APPLE, PRESENT COMPLICATED PROBLEMS

With some fruits the problem of the amount and nature of pruning desirable is still more complicated. Figure 87 shows a 45-

Fig. 87.—A 45-year-old apple tree unpruned for several years (compare with Fig. 88).

year-old apple tree that had not been pruned for a number of years. Its top was dense and brushy. Figure 88 pictures the same tree after it was pruned. Though this was a heavy pruning, the cuts were so distributed throughout the top that but few water sprouts were produced as a result of this treatment. Obviously much bearing wood was removed and the crop was materially reduced. The average yield of 36 unpruned trees like that shown in Fig. 87 was 17.9 bushels, and 36 trees pruned like that in Fig. 88 averaged 13.2 bushels. Pruning reduced the crop 25 per cent. On the other hand, 60 per cent of the apples from the

pruned trees were more than 2½ inches in diameter while only 40 per cent of those harvested from the unpruned trees were as large. Nevertheless, though pruning produced a marked effect on size of fruit, the difference was not great enough to compensate for the reduction in yield. It has often been said that in the apple, pear, and a number of other fruits, pruning results in a material improvement in grade through enhancing color and reducing scab, worm stings, and other blemishes, the theory being that better spraying is possible in pruned than in the

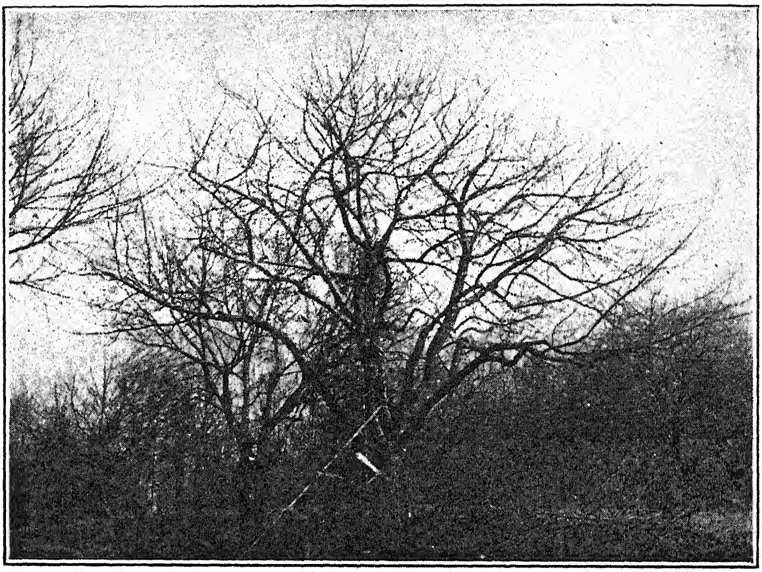


FIG. 88.—A 45-year-old apple tree after a moderately heavy pruning of the type usually given (compare with Fig. 87).

unpruned trees. This claim may have had some validity in the days of hand spraying, but with modern power-spraying machinery it is possible to coat foliage, bark, and fruit reasonably well regardless of pruning or its lack. In this orchard, given the ordinary spraying treatment by ordinary help, while 8 per cent of the fruits from the unpruned trees had to be placed in the "B" or cull grades because of insect, fungus, mechanical injuries, and small size, less than one-half of 1 per cent was placed in these grades because of poor color. The fruits from the pruned trees were but little better in color and freedom from blemishes, though only 2 per cent had to be graded down because of poor

size. The crop from the unpruned tree, as it finally graded out, actually sold for $9.14 above harvesting, packing, and selling costs; that from the pruned tree for $8.98. The owner paid a man 40 cents for an hour spent in pruning the tree shown in Fig. 88, and reduced its returns by 16 cents. The variety was rather poor and for its higher grades the market does not pay an especially high premium. Had it been of a more salable variety or had it been produced and sold in a district where only the highest grade brings a price that yields a profit, the financial balance might have been different. There is reason to believe, however, that the case represents fairly accurately conditions that obtain in most of the great commercial apple-raising sections of the eastern states.

WHY PRUNING IS VARIABLE IN ITS EFFECTS

Pruning, then, is variable in its effects. However, in trees of bearing age it almost invariably thins the crop. That there should be resultant increase in the size of individual fruits on heavily loaded trees is but natural. That total yield is sometimes reduced is not remarkable; neither is it surprising that in some cases the price received for the better grade exceeds the loss incident to reduced yields, while in other instances the converse holds true. These things are readily understood. That a practice used to invigorate a tree should actually invigorate it, and at the same time dwarf it seems a paradox. That one grower prunes his trees to promote wood growth and that his neighbor prunes the same variety for greater fruit production seems inconsistent.

Most of these apparent contradictions disappear upon reflection that pruning may mean any one of a number of distinct treatments and each of these may vary in severity and in time of application. Furthermore, these treatments may be given to trees of different growing and fruiting habits, in various states of vigor, at various ages and in various conditions of fruitfulness.

To illustrate how the amount of the pruning may affect results: other things being equal, the heavier it is, the more vigorous is the growth response. Some prune-growers, when their trees become full of unproductive brush, remove practically all of the bearing wood and cut the main branches back to stubs 2 inches or more in diameter, a process known as dehorning. They

thereby cut off the whole crop for the first year and the growth that season is generally so vigorous that there is not much of a crop in the second season, but after that, heavy yields of large fruits may be expected and no further pruning is done for 8 or 10 years or until growth slackens and the new wood becomes old, dense, and unfruitful. Lighter annual pruning does not result in any such increase in growth or size of fruit; neither does it result in wholly barren years. Over a long period there is probably no great difference between the two practices in their influence on yields.

Not only the amount, but also the nature, of the wood removed may influence the response to pruning. The removal of a given amount of wood from the tips of branches, essentially a heading back, has a greater stimulating effect on growth than an equal amount of thinning out, *i.e.*, the removal of laterals from points scattered along the branches. For this reason winter heading is much more common with fruits that bear fruit buds on shoots than with those that bear them on spurs.

In the young apple or pear orchard heavy pruning is undesirable because it dwarfs the tree. In the young peach tree it is desirable, in spite of this stunting effect, because failure to prune heavily may result in early cropping that stunts the tree still more. The difference in pruning treatment to obtain the same objective—the quick development of a large tree—is occasioned by the difference in the growing and bearing habits of the two fruits.

Not only does pruning vary in kind and amount, but the trees themselves vary in kind and condition and respond differently to the same type of pruning. Removal of terminal shoots would cut a peach crop severely the first year but have little effect afterward while the same treatment applied to an apple tree would have little or no effect on the next crop but might cut the crop harvested two years later and for several succeeding seasons; these divergent responses are associated with differences in the bearing habits. In the same variety, responses vary with the condition of the trees. On trees which lack nitrogen, pruning sometimes appears to stimulate the setting of fruit, but where the nitrogen supply is sufficient to ensure a heavy set, pruning does not further increase it. Pruning to increase the size of fruit on trees that are capable of producing large fruit without this treatment does not produce any measurable further increase.

Pruning intended to offset the effects of excessive production is not effective unless excessive production exists; it does not correct any defect unless the defect exists.

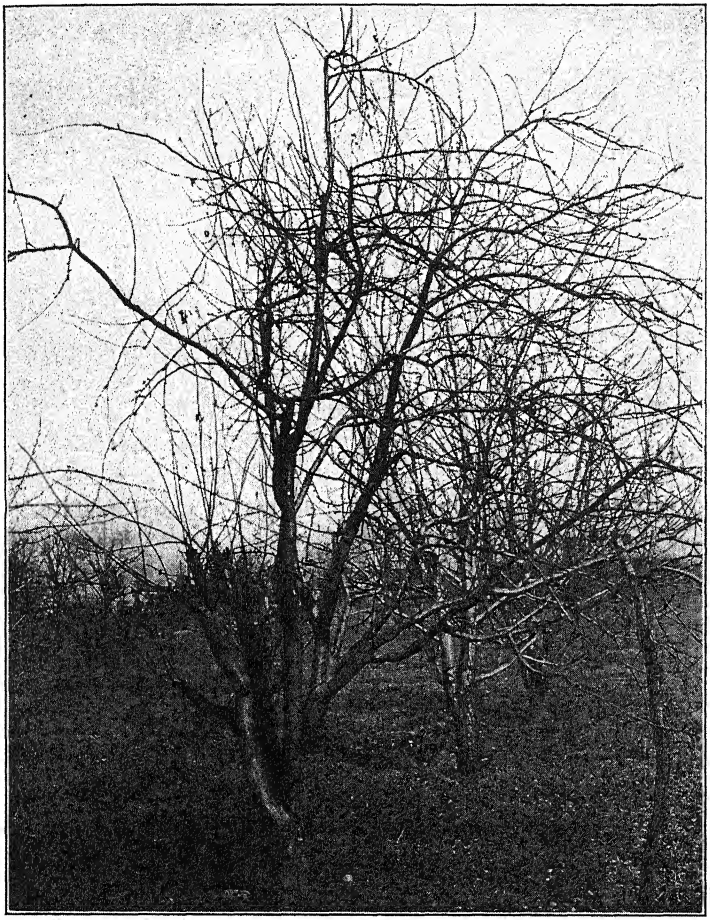


FIG. 89.—Half of the limbs of this tree were top grafted a year before the photograph was taken. Note that the remaining half of the tree shows little response to the heavy cutting incident to the grafting. The response to any pruning cut is extremely localized.

In brief, pruning is one variable in an equation that almost always contains other variables such as tree and price. The equation can be solved only by considering all the variables.

PRUNING EFFECTS LOCALIZED

Pruning is, in most respects, rather narrowly localized in its effects. Cuts on one large limb may stimulate growth, induce blossom bud formation, or enlarge fruit, as the case may be, and still be without effect on other limbs of the same tree. An accentuated example of this localization is afforded by a partly topworked tree, where the grafted branches develop numerous water sprouts while the ungrafted limbs show no response (Fig. 89). Even on one limb, response is most pronounced in close proximity to the pruning cuts. The only diffused effect of localized pruning appears when the pruning of one limb admits light to branches hitherto densely shaded.

THE PLACE OF PRUNING IN ORCHARD PRACTICE

What has been written will probably be interpreted as meaning that in the young orchard pruning is useful principally as it helps train the tree and keeps it from being dwarfed by premature cropping, and that in the bearing orchard it is useful mainly from the standpoint of effecting in one or another of several ways an improvement in grade. This, in general, is true, though there are some exceptional cases of special or secondary influences. Pruning may result in a somewhat different distribution or location of fruit on the tree, in an increase or change in type of shoot growth, in making fruit buds or shoot growth more or less hardy to winter temperatures; occasionally pruning influences regularity of bearing. These influences, however, are generally of secondary importance. Independent of any pruning practice or treatment, trees of bearing age will differentiate an abundance of fruit buds under ordinary conditions. In most cases, they will produce them annually. Seldom will good pruning help the situation, though frequently poor pruning will interfere with it seriously. In brief, pruning is not a universal, or even a general, means of increasing yield. On the other hand, it is often needed to prevent overbearing, to thin the crop, and to improve the grade. These are its principal functions.

Some of the effects sought by pruning may be secured by other methods. Fertilization and cultivation are often cheaper and more effective agents than pruning in promoting vigorous growth. Thinning the crop can in many cases be done more intelligently by removal of fruit in early summer than by pruning

before the blossoms open. Preference between treatments must be governed by considerations of expediency as occasions arise; no set rule can be laid down.

In most cases when the fruit grower uses his pruning shears or saw in the orchard he is in reality effecting an exchange, surrendering some advantages, such as earlier bearing or greater yield, in return for certain others, perhaps a larger or more rapidly growing tree or higher flavor or greater size of fruit. The bargain may be good or it may not. The individual who prunes without knowing what is given and what is received in exchange is like the purchaser of a ticket in a lottery, except that the latter knows the cost of his ticket. There is no magic virtue in merely cutting branches. Pruning is not a practice to be invoked, as it often is, in a dim hope that it may do some good; it should be used only to attain a very definite end. Lacking this, it is better omitted.

According to an old Greek legend, pruning was discovered first by Silenus, who observed that grape vines became more fruitful after they were browsed by his faithful ass. The city of Nauplia is said to have erected a statue to this animal for its services in teaching Silenus and, indirectly, all grape growers. Even though the legendary first pomological instructor was an ass, his followers in the orchards of the present need not be asinine in their pruning.

CHAPTER XVI

DIAGNOSING ORCHARD ILLS

Much, possibly most, of man's success in keeping animals and plants in useful condition depends on prompt recognition of departures from health, and accurate diagnosis of the underlying causes. Treatment of disease, though sometimes difficult and occasionally unavailing, is generally comparatively simple provided the diagnosis is correct. Accurate classification and identification, however, have been possible only when the causes of the various diseases have been understood. Lacking this understanding, man resorted to superstition and the medicine man of the savage, beating drums to scare the evil spirit away from the sick, was matched in comparatively recent days by civilized man's execution of witches accused of bringing disease to some unfortunate man or beast. In many cases pagan and Christian alike, regarding disease as a mark of divine disfavor, have resorted to prayer for deliverance from it.

As with animals, so it was with plants. There prevailed the same tendency to regard diseases of crops as punishments visited on an offending individual or people, and certain of the old pagan gods were invoked in behalf of the threatened crop. In very early days the connection between environment and the occurrence of certain plant diseases was in some measure realized and effects of excessive cold, heat, and drought were recognized. The work of insects was, in some cases, obvious. Fungous diseases, however, were not understood and the name "Flibbertigibbet" designated a creation of the popular imagination that was at one time supposed to produce squint-eye and cross-eye in men and mildew in grain. Fungi were explained variously as fairy stools and witch's butter; the term "fairy ring," applied to a fungus which grows in a widening circle in grass plots, commemorates the old belief that the ring marked the path of fairy dancers. Knowledge of the nature of fungous diseases was virtually impossible until the microscope was invented; actually it did not develop until many years after this. In

1731, when the use of the microscope had been known for some years, Philip Miller, at that time the leading gardener in England, could offer no more definite suggestion as to the nature of mildews than that they were due to "a dry Temperature in the Air—which stops the Pores of Plants and prevents their Perspiration, whereby the Juices of Plants are concreted upon the Surface of their leaves." For a century or more after this, practically all attempts to account for diseases centered upon soil and climatic conditions; this resulted in the accumulation of a valuable fund of information about adaptability of fruit trees, but left many diseases unexplained.

Understanding of the relation of fungi to plant disease, when it was finally achieved, did not itself suggest methods of control, but it did permit some sort of reclassification of diseases and it explained some cases where evidence seemed hopelessly conflicting. The "frozen-sap blight" which had troubled and puzzled fruit growers for many years and had been attributed variously to winter killing, borers, aphids, lack of iron, lack of potash, atmospheric humidity, atmospheric electricity, root grafting, and numerous other more or less plausible causes, was found finally to be in reality a group of separate disorders, due respectively to sunscald, to winter injury, to a bark canker caused by a fungus, and to fire blight—a bacterial disease.

The rapid growth of the lists of injurious insects and fungi brought under some sort of control has tended to focus attention on diseases of organic origin, somewhat to the neglect of those due to other agencies. Study of environmental factors, dominant a century ago, has been relegated to comparative obscurity. Fruit growers have heard and read so much about insects and fungi that the appearance of any disorder in their trees sets them to looking for insects or fungi; sometimes this search is prosecuted so eagerly that it leads to blindness to other causes which should be obvious.

RECOGNIZING REGIONAL OR SECTIONAL PECULIARITIES

In diagnosing tree disorders, experience quickly teaches the usefulness of relative probabilities as a guide, partly in indicating which disorders are most likely to occur and partly in eliminating others. Regions have their peculiar susceptibilities and immunities; alkali troubles in humid regions, root freezing in orange groves, nematodes in regions where cold winters prevail, need not

be expected. Curculio is abundant in eastern plum orchards and unknown on the Pacific coast. Sectional peculiarities, narrower than regional, sometimes prevail. In Oregon fire blight is a veritable scourge in the Rogue River Valley and virtually unknown in the Willamette Valley, a hundred miles or so to the north; it is sporadically rather prevalent in Massachusetts and barely known in Maine. Differences associated with location, even within the same orchard, should be recognized; a high and dry spot may be safe from drainage difficulties but particularly susceptible to root freezing (Fig. 50); seepage or alkali may kill trees in one corner of the orchard while the remaining trees are uninjured. Susceptibility to various features of environment vary; in Michigan peaches are more liable to root freezing than apples, and likewise dwarf pears than standard trees of the same varieties; various species and root stocks differ in their susceptibility to alkali injury. Most fungi are limited to certain host species; fire blight, for example, is not common in plum blossoms, and brown rot does not work on apple blossoms. Study and experience indicate many similar methods of narrowing down the number of diseases and causal agents possible in any given case.

Even with these eliminations made and short cuts utilized considerable close discrimination remains necessary. There are literally dozens of kinds of insects that occasionally injure a single species of fruit; the same species may be attacked by as great a variety of fungi and in addition, suffer various injuries caused by unfavorable weather conditions, by deficiencies of soil, or by other factors. The kinds of pests that infest all the more common fruits literally run into the hundreds. To make matters worse, the causal insect may be very difficult to find. Perhaps it is microscopic in size, or it may work only at night, or it may take a form that would not be recognized except by a trained entomologist. Many bacteria and fungi cannot be identified positively without a microscope. Only specialists can hope to acquaint themselves with even the majority of these orchard pests or merely to recognize the work of each and every kind. Fortunately neither of these things is necessary for the fruit grower. He should, however, learn to recognize quickly and accurately certain characteristic types of injury—in other words, to classify, if not identify, any trouble. In most cases, accurate classification permits the outlining of an effective treatment.

STUNTED, WEAK GROWTH

Short annual growth in the terminal shoots, a marked yellow cast and sparseness of foliage, and a general growth habit conveying an impression of "weakness" may be symptomatic of several rather distinct primary causes, which act upon the tree ultimately in the same way. It is often difficult to differentiate with certainty between the various factors that check growth, and to determine exactly which of them has produced a particular case, especially when there may be a combination of causes, but careful study usually permits a working diagnosis. This condition may be considered to indicate primarily a lack of nitrogen or of moisture or of both. The lack may be due to deficiency in the soil, without any unsoundness in the tree; here the remedy lies obviously in treating the soil. On the other hand, nitrogen and moisture may be abundant in the soil, but the tree may be unable to absorb them becaues of injury to the roots; freezing injury, waterlogging of the soil, woolly aphis (on apples), black aphis (on peach), nematodes, fire blight, gophers, pine mice, alkali, or mushroom root rot may have this effect. In other cases the soil may be favorable and the roots for a time sound, but conduction may be obstructed at the collar or slightly above or below it; this condition is likely to follow destruction of the bark by freezing, fire blight, mice, rabbits, fire, borers, or (in the peach tree) excessive use of paradichlorobenzene. Vigorous sprouting from below the injured area is likely to follow injuries of this sort; otherwise the roots die within 2 or 3 years and with them the top. When only a portion of the tree shows these symptoms the trouble is likely to be seated in the roots or on the trunk on the corresponding side (Fig. 49). Disorders of this kind due primarily to poor soil, a high water table, or winter freezing, are likely to be more or less localized in the orchard. Those due to rodent, insect, or fungus attack are more likely to have a random distribution. Examination of trunk and crown shows at once whether there has been girdling and the condition of the tissues will usually indicate rather clearly what has been responsible for it. Mice and gophers leave characteristic teeth marks. Blight cankers may be recognized by their characteristic streaks and stains and the extremely bitter taste of the affected tissues. The various crown rots are not so easily distinguished from one another, but this is not necessary because the remedial measures are essentially the same for all.

If no evidence of girdling is found, excavation will reveal the distribution and the condition of the root system. If it is shallow but apparently in good condition, poor growth may be due to drought or a poor nutrient supply. The character of the soil itself; *i.e.*, its apparent productivity, usually indicates which of these two factors is of greater importance.

If examination shows the upper roots alive and the lower roots dead, the condition may be attributed to a high water

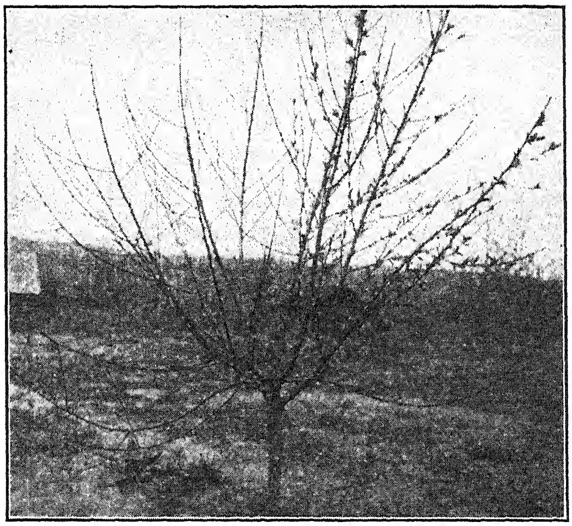


Fig. 90.—Dieback due to winter cold. The ends of the twigs that show life, as well as some entire limbs, were killed.

table existing long enough to kill these roots, and improvement of drainage is the only lasting remedy. If, on the other hand, the upper roots are dead while the lower survive, freezing is likely to have been the cause and cover crops the preventive measure.

DIEBACK

Dieback of branches falls into two groups, according to its occurrence on twigs that have recently been growing vigorously or on those which have for several years been making scanty growth. If the tips of a branch which grew vigorously in the previous year fail to resume growth in the spring, though the remainder of the branch seems normal, it is probable that the injury is due to winter freezing. This is rather common in

peaches (Fig. 90), grapes, and the brambles and may occur in any of the other temperate zone fruits. When, however, a vigorously growing shoot in full foliage dies, with the leaves turning brown and hanging in place, fungous or bacterial attack is likely to be the cause. Fire blight is a common cause of this killing back in pears (Fig. 91), quince, and apples. A super-

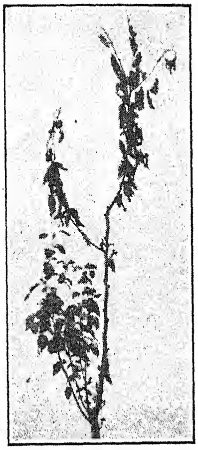


Fig. 91.

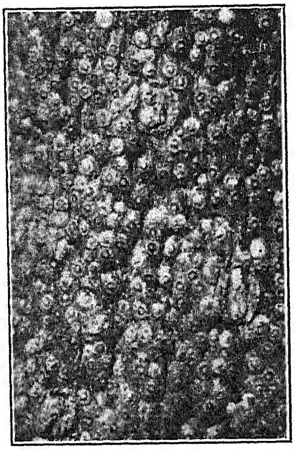


Fig. 92.

Fig. 91.—The branch on the right has been killed back by the fire blight organism. Note how the dead leaves remain attached to the twigs in this form of dieback.
Fig. 92.—San José scale insects (view slightly enlarged) encrusting an apple limb.

ficially similar appearance is presented by apple shoots cut by a twig miner, but careful inspection reveals the insect work at the point of fracture. A disease of the raspberry displaying similar symptoms is due to a fungus.

Dieback in branches which have for several years made little growth is likely to be merely an advanced stage of the disorder already discussed resulting from lack of nitrogen or moisture. Indeed, the difference between the two troubles is in degree rather than in kind. Especially is this true of dieback that is more or less general throughout the tree. It is likely to progress farther from year to year. Climbing cut worms, eating out the opening buds, or canker worms or fall web worms, destroying the foliage after it has developed, may leave a branch, vigorous or weak, with wood sufficiently unripened to cause dieback in the ensuing winter; injuries of this sort are usually confined to isolated branches

here and there. When dieback has been followed promptly by vigorous growth of shoots and water sprouts from lower portions of the limb it is likely to have been produced by winter killing; however, dieback due to a lack of nitrogen or moisture may be followed by vigorous growth from the lower part of the branches in a season of heavy rainfall.

Dieback in branches or death of the tree may result also from the attacks of various scale insects, particularly the San José scale (Fig. 92) and the oyster-shell scale (Fig. 93); their presence is revealed by careful examination of the bark. Peach, plum, and apple trees may be weakened or even killed by the attack of borers

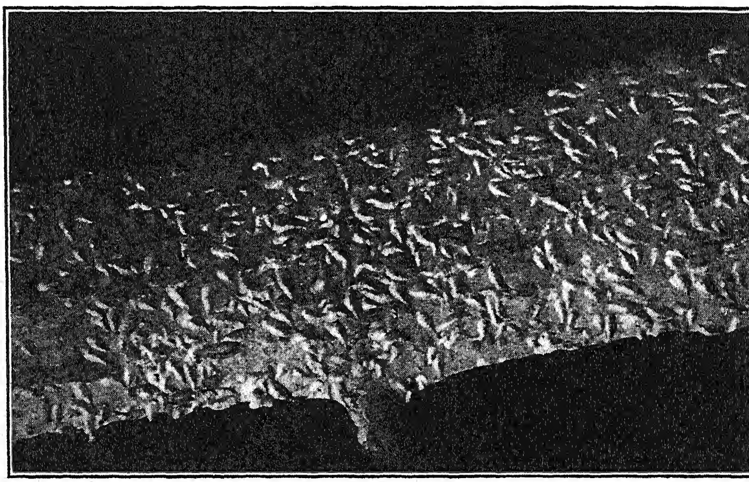


FIG. 93.—Oyster-shell scale on an apple branch. (View slightly enlarged.)

at or near the ground; the work of the larvæ is revealed by gum and by the "frass" or "sawdust" that accumulates at the openings of their tunnels. Small, clean holes in the trunks or limbs of plums and cherries, are caused by the pin-hole or shot-hole borer; this insect, however, is not the source of any significant amount of damage and its presence merely indicates a prior weakening of the tree from some different cause. "Weakness," slow growth, and dieback may likewise be the consequence of repeated destruction of foliage by insects such as pear psylla, slugs, leaf miners, and the various "caterpillars," or by leaf-infesting fungi such as peach-leaf curl, cherry-leaf spot, and apple scab; these do not attack the twigs, but the injury to the leaves is in many

cases injurious to the tree itself. Marked bending of vigorous shoots, particularly water sprouts, is an indication of previous aphis injury. In peach trees dieback due to yellows occurs only after an abnormal type of growth, readily recognized once seen, preceded or accompanied by premature ripening of fruit in the parts affected.

CANKERS

Localized injuries to the bark, generally designated loosely as "cankers," may be due to one or more of several causes. They are all characterized by destruction of the cambium layer at the affected point, giving rise, as growth proceeds in surrounding uninjured tissues, to sunken areas of greater or less extent. Some are produced by winter injury or by sunscald (Fig. 94). Death of the bark in the crotches is in many cases due to winter freezing (Fig. 48). Sunscald generally occurs on the southwest side of

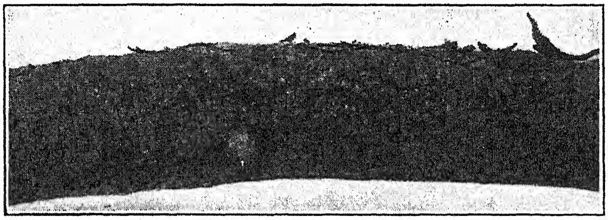


FIG. 94.—A sunscald canker on an apple limb.

the trunk, on the southwest side of limbs pointing to the north, or on exposed horizontal limbs pointing in other directions, in short, wherever the sun strikes long in early afternoon. It is most common in smooth-barked limbs of 2 inches or more in diameter. Smoky-appearing, loosely defined cankers on apple limbs are characteristic of black rot (Fig. 95); this fungus commonly invades sunscald cankers and extends them. Sharply defined cankers in the apple and pear, particularly in smooth bark, are likely to indicate fire blight. A canker of this kind that has nearly girdled a small limb is depicted in Fig. 96. Apple-tree cankers which show numerous white elliptical marks when the bark is lifted are produced by the "blister-canker" fungus, common in the Mississippi Valley (Fig. 97). A lesion characterized by a swelling on one side of a small twig with several callus lips on the other side, indicates the work of the European canker.

In the Pacific northwest anthracnose cankers may appear on small apple limbs (Fig. 98); in the southern states apple blotch produces cankers on the twigs (Fig. 99). In peaches, arsenical injury

FIG. 95.—A black rot canker on an apple branch.

from spraying or dusting may cause small cankers on small twigs, sometimes exuding much gum (Fig. 100); certain bacteria and fungi produce a somewhat similar appearance, but these do not work in vigorous trees. "Gummosis" may lead to the formation of a canker in cherry trees that in some respects resembles that

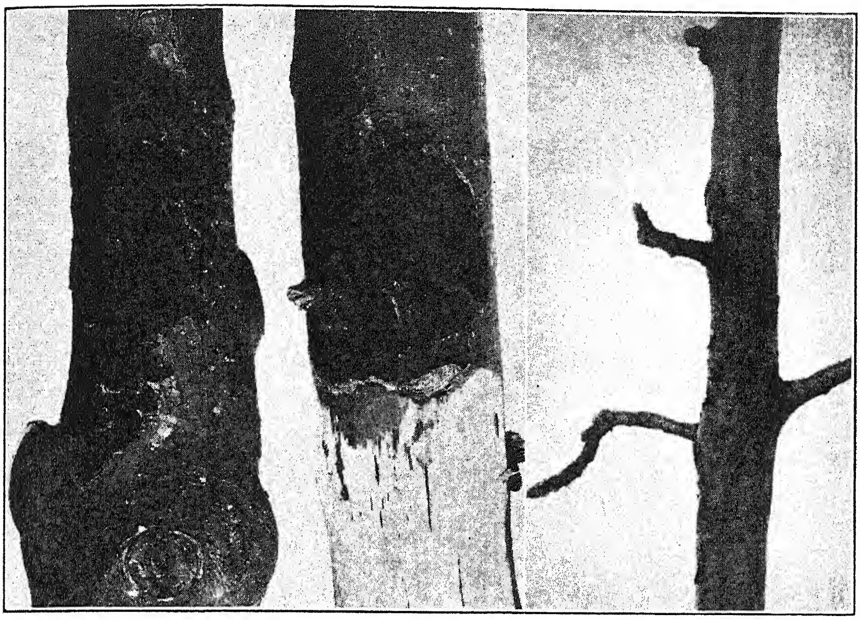


FIG. 96.—Two cankers caused by the fire blight organism. That at the left has completely girdled the branch and the entire branch should be cut off well below where any trace of the disease is evident. The canker in the center is localized and can be cut out, as shown in the figure at the right. Note the discoloration of the wood, characteristic of fire blight cankers. Wounds left in fire blight cutting should be sterilized.

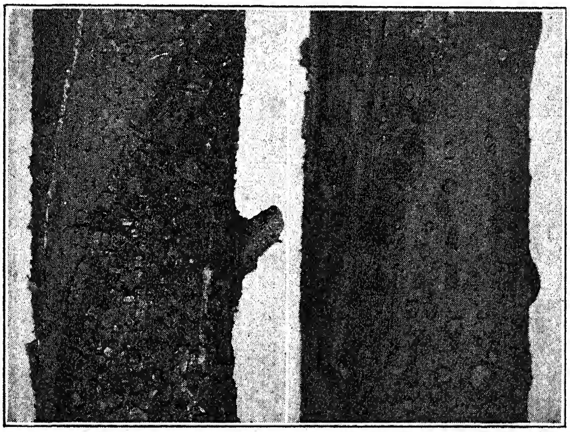


FIG. 97.—Illinois blister canker on apple branch. Note the characteristic blisters on the branch at the right, where the bark has been removed.

caused by the fire blight organism in the apple and pear. The continued rubbing of one limb against another may sometimes cause a canker.

Cankers of all kinds are more or less serious, for they interfere with sap flow. If they entirely girdle the twig, limb, or trunk, as is very likely to happen in the case of those caused by fungi or bacteria, they lead to the subsequent death of the portion above.

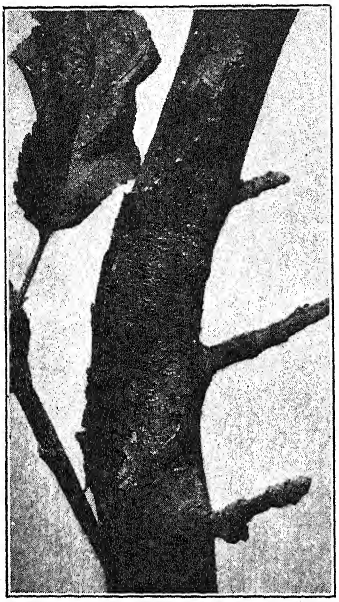


Fig. 98.—Canker of the apple tree anthracnose, a disease peculiar to western apple regions.

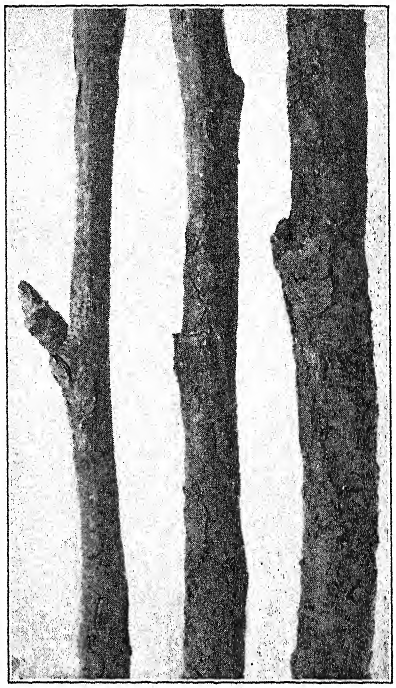


Fig. 99.—Characteristic twig lesions of the apple blotch fungus. When infection is severe the twig is girdled and killed.

This may come quickly, as with fire-blight cankers, or slowly, as with black-rot or bitter-rot cankers. The dead tissues are subject to the attacks of wood- and bark-rotting fungi and these secondary parasites often spread from the cankered areas to sound tissues, perhaps in the end causing more trouble than the original canker. The canker-forming fungi which invade the tissues of smaller branches and spurs, such as apple blotch, are only a little less serious than those which invade larger limbs, for they girdle

and kill the fruiting portion of the tree and reduce it to a condition of relative unproductivity as effectively as those diseases that cause more conspicuous lesions.

To be distinguished from true cankers, however, are cases of normal bark cleavage due to the formation of cork which becomes cut off from adjoining bark layers (Fig. 101). These sunken areas are often believed to indicate the presence of some injurious

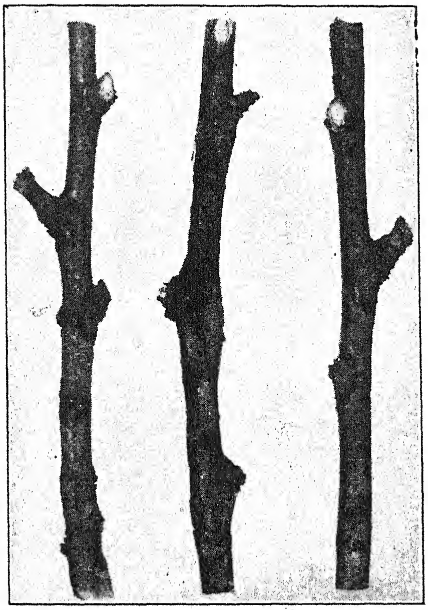


Fig. 100.—Cankered areas on peach twigs caused by arsenical sprays.

fungus or bacterial disease, when, as a matter of fact, they are entirely harmless.

GUMMOSIS

Gum flow or gummosis is confined to stone and citrus fruits. At the collar of the tree—sometimes even in the branches—and associated with "frass," or "sawdust," it indicates the work of borers. In the crotches it may be an aftermath of winter injury. In the Pacific northwest and also in some of the eastern states some cases of gummosis of sweet cherries are caused by a bacterial infection; these cases are generally rather localized and associated with canker-like lesions (Fig. 102). Generalized gum flow

in trunks and branches of any of the stone fruits may be a symptom of injury to the roots; it is common in trees in poorly drained land, or in trees suffering from excessive drought, mushroom root rot, root injury from freezing, or heavy borer infestation. In

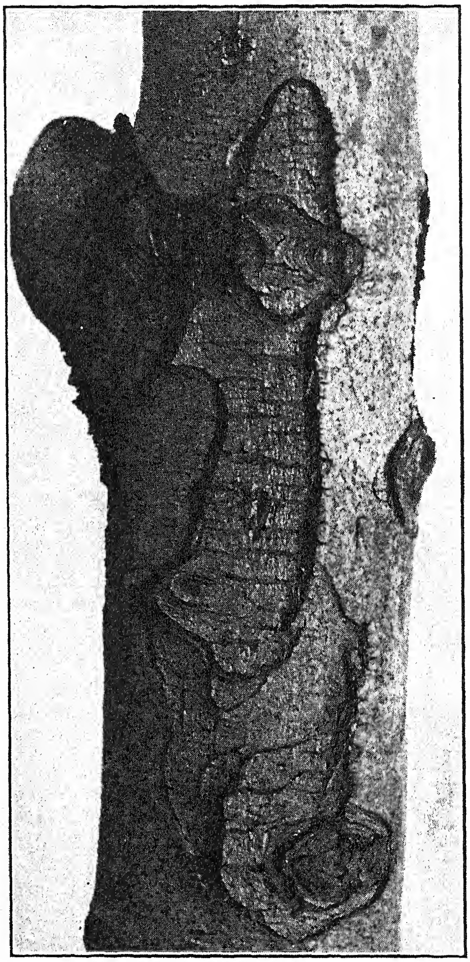


Fig. 101.—Harmless surface "canker" on pear branch. "Cankers" of this kind are the beginning of the rough bark stage, and are perfectly normal.

sweet cherries it sometimes accompanies excessive pruning or black-heart injury.

Slight gumming may take place where the tissues are apparently sound or where, perhaps, there is a slight injury, such as a

growth crack, in the bark. These slight exudations result in no injury to the tree. In apples and pears a viscous fluid somewhat resembling gum may exude, in the spring and summer, from very active cankers of fire blight; this, however, does not accumulate and harden as does the gum found in sweet cherries.

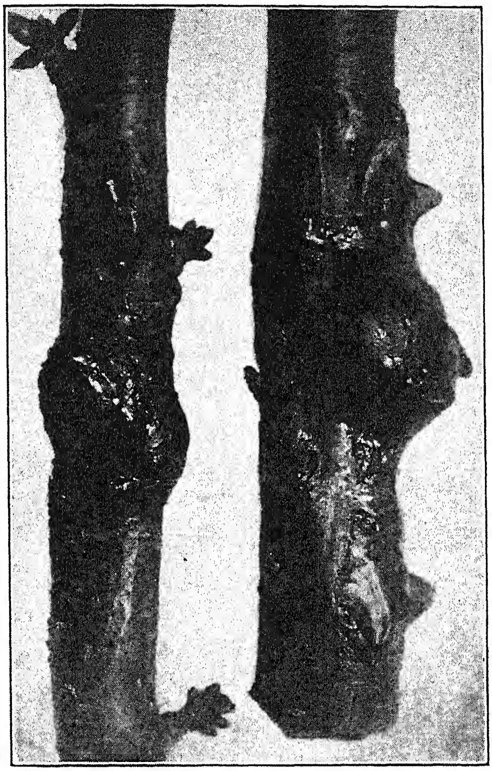


Fig. 102.—Gum exudations accompanying the canker-like lesions caused by the bacterial gummosis of the sweet cherry.

ROUGH BARK AND EXCRESCENCES

Rough, wart-like or gall-like excrescences frequently occur on the roots of nursery stock. These growths are generally called crown gall (Fig. 103) or hairy root, depending on the form that they take. In some cases they are due to invasion by a plant parasite; in others to the formation of an extra large amount of callus tissue incident to the healing over of a defective graft union. If the galls are of the latter type, the trees will soon out-

grow them and suffer no harm, but if they are caused by parasitic organisms they are likely not only to check growth and lower yield but to shorten the life of the plant and to spread to others that are healthy.

Some varieties of plums are subject to wart-like excrescences on the twigs and limbs, caused by a fungus that is both designated and described by the term "black knot" (Fig. 104).

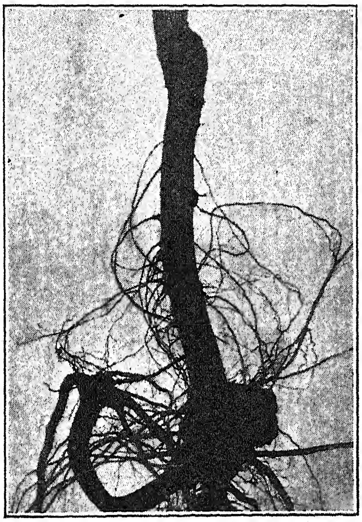


FIG. 103.—Crown gall on a nursery tree.

FIG. 104.—Black knot on a small plum branch.

A tearing and roughening of the bark and wood of the shoots and smaller twigs of fruit trees of many kinds, that sometimes looks as though it might have been done with a saw, is caused by the egg-laying puncture of certain insects—*e.g.*, some of the cicadas, tree hoppers, etc. (Figs. 105 and 106). Closely resembling injuries of this kind is the type now and then caused by hail (Fig. 107). Hail injury, however, will be confined to one side of the limb—that from which the hail came; egg-laying punctures are likely to be found on all sides of the branch. Injuries of this

type are purely mechanical and, unless so severe that they cause the branch or twig to break, heal of their own accord.

Small wart-like growths on apple twigs, often giving them a more or less pimpled appearance (Fig. 108), are due to prior attacks of the woolly aphis.

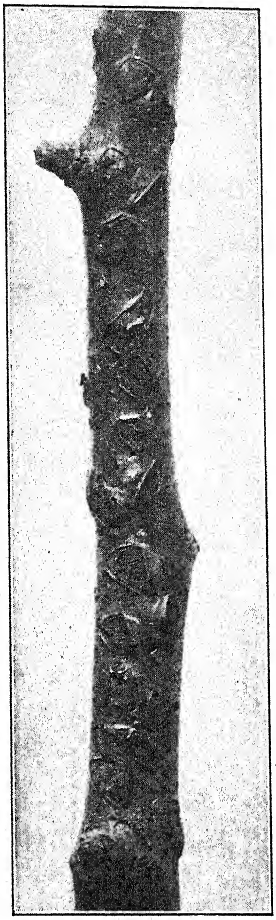


FIG. 105.—Scars due to the egg-laying punctures of tree hoppers.

BARK SPLITTING

Vertical splits in the bark, usually close to the ground (Fig. 44), are generally caused by sharp winter freezing. Young trees, especially those that have grown rather late and vigorously

and consequently have not matured well, are susceptible to this injury. Unless the bark separates from the wood a good share of the distance around the trunk, these wounds usually heal over fairly promptly without requiring attention. Oftentimes, however, the same conditions that lead to bark splitting, in addition cause black heart, which is a more serious matter.

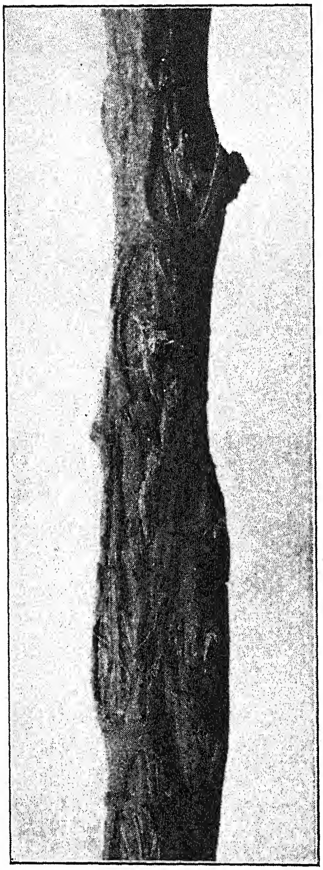


FIG. 106.—Scars on an apple shoot caused by the egg-laying punctures of the 17-year cicada, or locust.

YELLOW, SPARSE, OR DWARFED LEAVES

Lack of normal green color in leaves may result from any one of several distinct conditions. An apple tree which is in its "off year" has lighter-colored foliage than one which is in its bearing year; a non-bearing branch will have lighter foliage than a bearing branch on the same tree; this condition is quite normal.

More pronounced yellowness of leaves may indicate red-spider attack, particularly if the leaves are "dry and brittle" to the touch. Careful inspection of the under sides of leaves infested with red spiders usually reveals the presence of the insects themselves and of their fine delicate webs. Paleness which is due to mottling with small grayish spots and is often called "yellows," characterizes leaf-hopper work and, in the pear, the work of the psylla. Leaves presenting these symptoms are ordinarily of normal size and shape. Furthermore, the symptoms are likely to appear rather suddenly, coincident with the attack of the insects.

The midseason development of a yellow tinge in the foliage, accompanied by a tendency to curl along the midrib in hot dry weather, is an indication of trouble in the roots or at the collar (Fig. 109), or it may indicate that the tree is suffering from

drought. Trees that have been in the orchard only a few years and have never made satisfactory growth are likely to show these

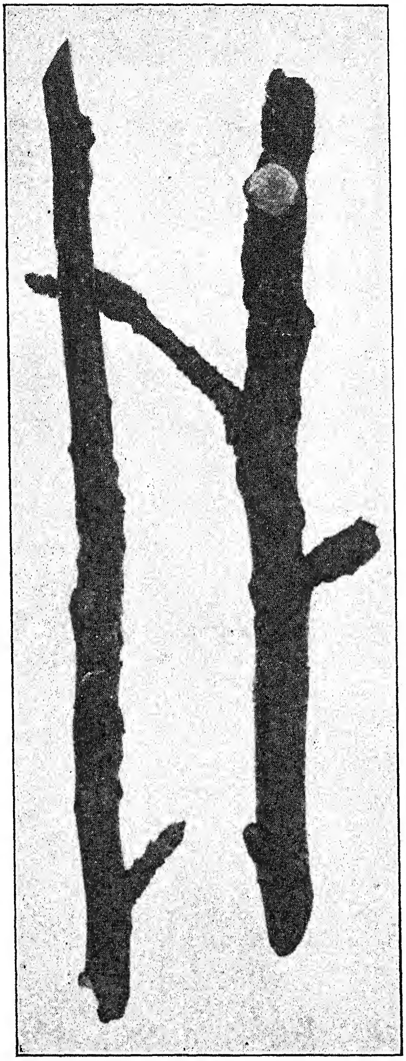


Fig. 107.—Hail-injured apple twigs. Injuries due to hail are usually confined to one side of the branch.

symptoms. Older trees are more likely to show them following injury to the crown, the destruction of surface roots by deep cul-

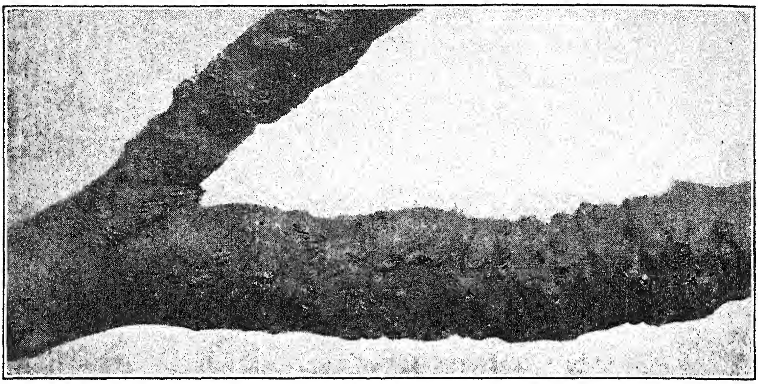


FIG. 108.—An apple branch showing roughening caused by the attack of woolly aphids.

FIG. 109.—This tree, at 4 years of age, is no larger than it should have been after a year's growth in the orchard. The leaves are of normal size and not diseased; but they exhibit a characteristic folding together along the midrib. Their appearance suggests drouth injury. Injury of some kind to the root system, *e.g.*, partial killing due to high water table or deep freezing, or, in the peach, to root aphids—may be suspected.

tivation or winter freezing or the killing of the lower roots by a high water table. They sometimes follow winter injury of the black-heart type.

The sudden yellowing of many, particularly the older, leaves, followed by their premature dropping is often caused by the application of certain kinds of spray materials. Especially is this true with the stone fruits, though it is by no means uncommon in apples and pears. It is greatly influenced by weather conditions and even by hardness or softness of the water used in spraying. Premature defoliation of this kind may or may not be preceded or accompanied by spotting of the leaves. A similar yellowing and premature defoliation is caused by the attacks of

FIG. 110.—The tree on the left has been almost completely defoliated in mid-season by the cherry leaf-spot disease; the tree on the right shows healthy foliage that has been protected by proper spraying. Defoliation like that shown on the left renders the tree very susceptible to winter injury.

certain fungi—*e.g.*, the leaf-spot diseases of the cherry, plum, peach, and currant.

A distinctly yellowish or pale green cast to all the leaves together with some reduction in their size (but without any curling) and accompanied by weak twig growth, indicates "starvation," due either to a lack of soil nitrogen or moisture, or to injury to the roots or the conductive system. Differentiation between these several causal agents has been discussed under Weak, Stunted Growth.

Yellowing of leaves accompanied by dwarfing and curling, is discussed later under the heading of Curling of Leaves.

Chlorosis is a term applied to a condition in which the leaves, particularly the younger leaves, are entirely yellow or almost

white, practically no green pigment being developed. It is generally a sign of a lack of available iron and is found principally on alkaline or neutral soils or in those of a calcareous nature. A related disorder, known as "frenching," is characterized by the disappearance of most of the green coloring matter from between the leaf veins, while the veins remain green, imparting to the leaves a mottled appearance. It is apparently associated with potash deficiency or with overbearing.

Sparseness in foliage, without accompanying yellowness or marked reduction in growth, may indicate loss of leaves from

FIG. 111.—A peach twig infected with peach leaf curl.

attacks of fungi such as leaf curl, scab, leaf spot, bacterial shot hole, spray burn (Fig. 116), or it may signify that the tree bore an excessively heavy crop the previous year or that it has recently received winter injury in the form known as black heart.

PURPLING OF LEAVES

The development of a marked purplish tinge in leaves in late summer or early fall is usually an indication of injury of some kind to the root system or the crown. Unless the purple color appears comparatively early or unless it is very marked the condition may not be serious, but recurrence of the symptom year after year suggests the need of employing remedial meas-

ures. Pear leaves may assume a bronze tinge under these conditions, while normal leaves are still green.

CURLING OF LEAVES

When leaves curl upward along the midrib to an abnormal degree, during hot, dry weather, a temporary shortage of water is indicated. This may be due to soil conditions, and it is particularly common in soils overlying hardpan or rocks; very often, however, it is one of the earliest evidences of injury to

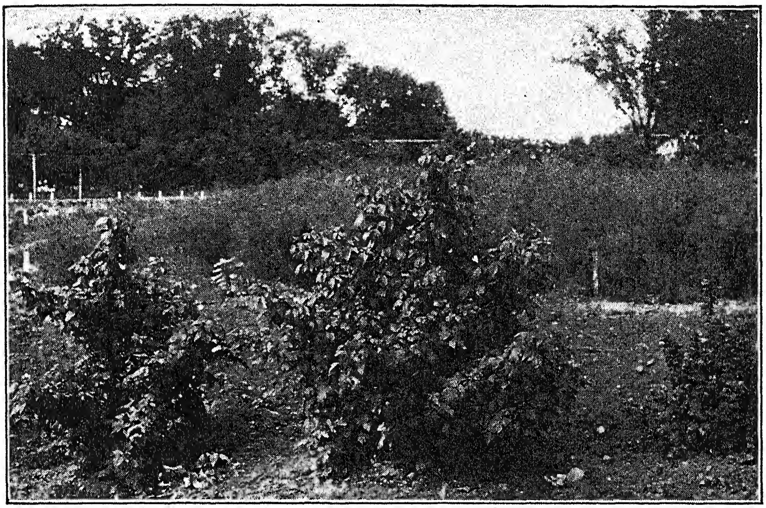


FIG. 112.—In the center a healthy Cuthbert raspberry plant; on the left one infected with mosaic; on the right one infected with leaf curl.

the roots or the collar of the tree (Fig. 109). It may also indicate the presence of black heart in the wood.

When leaves curl backward from the midrib and the midrib itself curls backward, without any yellowing, aphids are generally the responsible agent. If they are not actually present at the time of observation, traces of them can generally be found, in honeydew blackened by a sooty mold, or a few dead individuals, killed perhaps by parasites. Peach leaves curl backward along the midrib when affected by "leaf curl," a fungus disease; the leaf itself, under this attack, takes on a characteristic thickened, velvety and roughened appearance which permits identification (Fig. 111).

Curling, accompanied by a marked dwarfing and yellowing of the foliage, is characteristic of both peach "yellows" and "little peach," two related diseases that occasionally assume epidemic form. Greatly reduced vegetative growth, shortened internodes, and dwarfed insipid fruits also characterize these diseases. The causal agents are not known.

Curling, accompanied by a marked dwarfing and often some mottling, characterizes a group of disorders that may be designated as diseases of the mosaic or virus type. They are especially serious among the bramble fruits (Fig. 112).

LEAF ROLLING

The distinct and rather compact rolling of a leaf or, more frequently a leaf cluster or a growing tip, is usually due to a caterpillar that webs together the affected parts. Presence of the web and the skeletonizing of the leaf or leaves on the inside of the roll, aid in identification. Strawberries and apples are most frequently attacked.

ROSETTE

A disorder characterized by very much shortened internodes and dwarfing but unaccompanied by curled foliage, giving rise to a rosette-like appearance of the new growth, is sometimes designated as rosette, occasionally as "little leaf." It is sometimes mistaken for a disorder of the virus or mosaic type, but apparently is usually due to disturbed moisture and nutritive relations. Trees on droughty soils or those deficient in organic matter seem particularly susceptible and the application of barnyard manure or the use of soiling crops generally alleviates or entirely remedies the condition.

MILDEW

Mildews affecting the foliage and twigs of fruit plants are of two main types—downy and powdery. Their names are sufficiently descriptive to make identification possible. Though they are capable of causing serious injury if not dealt with properly, they are surface parasites and are easily held in check by proper control measures. Grapes, apples, and gooseberries are the most commonly affected among deciduous fruits.

BROWNING OF LEAVES

When full-grown apple, pear, and quince leaves turn brown and die, and the young shoots bearing them turn brown and wither (Fig. 91), fire blight is likely to be the cause. Injury of the same general type in the raspberry plantation is caused by the cane-blight organism. Slow growth of the leaves of a whole branch or tree in the spring, followed by their turning brown and dying, and with them the tree, is a characteristic

Fig. 113.—Apple scab on a leaf.

symptom of root injury from freezing or perhaps traces back to an old collar injury working through destruction of the roots.

Localized brown—sometimes black—spots in the leaves may be caused by spray burn or by fungi. Leaves which have been markedly curled from aphid attack are likely to turn brown before dropping. In the apple excessive applications of readily soluble fertilizers may be followed, in dry summers, by browning of the margins of the leaves; this browning is generally more

sharply defined and more regular in distribution than that characterizing spray burn.

LEAF SPOTTING

Leaf spot, scab, rust, blight, shot-hole, and frog-eye are terms in common use for a large group of fungi causing a spotting of the leaves of fruit plants. Frequently the spots are so numerous that they run together, causing large irregular lesions. The spots caused by the various fungi here grouped vary greatly in size, color, shape, and general appearance (Figs. 113 and 114). In some attacks, the tissues invaded by the organism are cut off and drop out of the leaf, giving it a perforated or "shot-hole" appearance. In many cases, infected leaves turn yellow and fall prematurely (Fig. 110). Some spots are due to the presence of

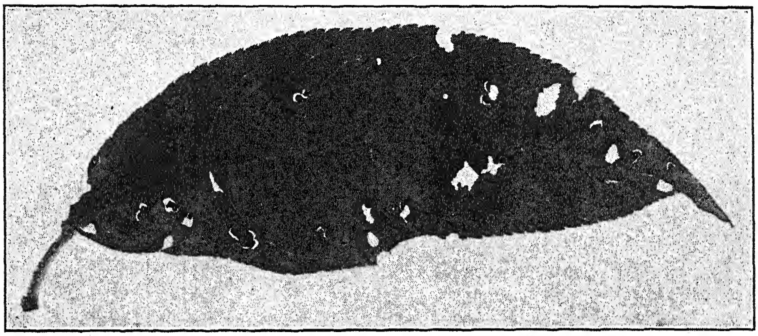


FIG. 114.—Shot-hole in a peach leaf, caused by a bacterial infection (compare with Fig. 116).

scales (Fig. 115), blister mites, or other insects. In any case, the effect of these diseases or insects is to weaken the plant as a whole, to reduce yield and grade of fruit, to lessen vegetative growth, and to increase susceptibility to winter injury.

Lesions in general appearance more or less like those caused by certain fungi are sometimes caused by spray applications. These may take the form of either round or irregularly shaped spots or of brown areas along the margins of the leaf and they may be caused by almost any of the sprays when used in too great concentrations or in too large amounts (Fig. 116). Seasonal or environmental conditions may render foliage particularly susceptible to spray injury. Even the best of growers often have difficulty in distinguishing between some of these forms of spray burn and certain of the leaf-spotting fungous

lesions. Appraisal of the conditions under which the spotting appears, as well as the appearance of the spots, helps in determining the cause.

FIG. 115.

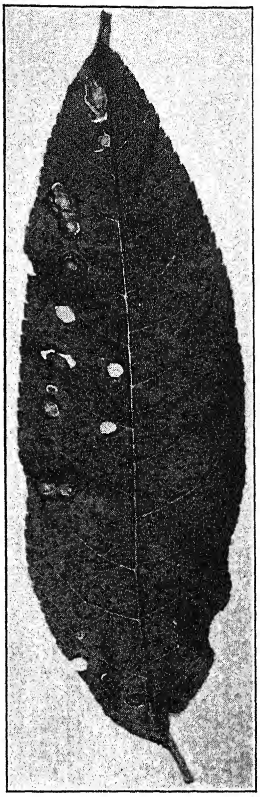


FIG. 116.

FIG. 115.—An apple leaf infested with San José scale. The scales themselves appear in the photograph as the light centers of the dark spots. These spots are usually dark red or reddish purple.

FIG. 116.—A shot-hole appearance in a peach leaf caused by spray injury (compare with Fig. 114).

DESTRUCTION OF LEAVES

Leaves may be eaten, partly or wholly, as by "caterpillars." They may be "skeletonized," as by slugs (Fig. 117). Peach and plum tissue may be attacked by bacteria which cause portions of the tissue to turn brown and these spots may later drop out, leaving holes in the leaves. "Leaf-miners" may work in

the substance of the leaf, producing "blisters" or making tunnels which are readily observable.

Dropping of leaves may be caused by acute fungus attack or it may be due to a chronic physiological disturbance. Cherry-leaf spot, peach-leaf curl, and apple scab, may cause partial or

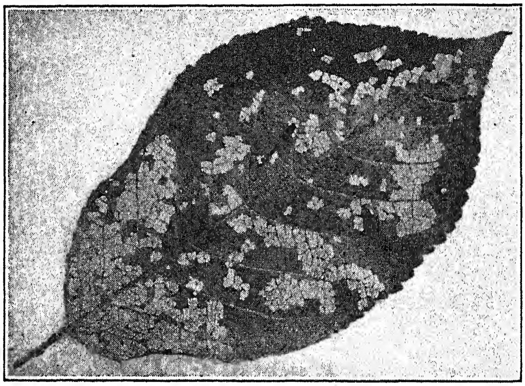


FIG. 117.—An apple leaf, partly skeletonized by slugs.

complete defoliation of the tree, such as is shown in Fig. 110. In midsummer, leaf fall from one limb is likely to be the result of injury to trunk or roots on the corresponding side, and often presages the ultimate death of that limb.

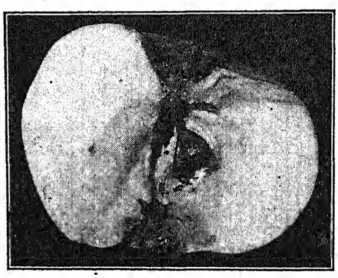


FIG. 118.—Longitudinal section through a "wormy" apple. These tunnels were caused by larvæ of the codling moth.

WORMY FRUIT AND STINGS

The most important of the fruit-infesting insects of deciduous fruits is the codling moth. It produces most of the so-called "wormy" apples, pears, and quinces, and not uncommonly is found in the fruits of the peach and many wild relatives of the

apple, like the haw. Figure 118 depicts a longitudinal section of an apple showing its characteristic tunnels. Worm infestation in the stone fruits is generally due to attacks of one of the

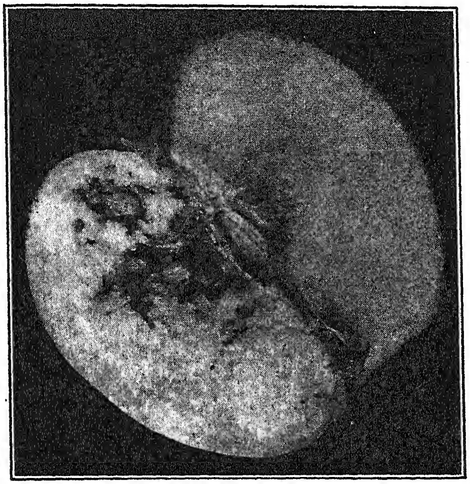


FIG. 119.—Tunnels in the flesh of the apple caused by the maggot or "railroad worm."

curculios (Fig. 121) or of the oriental peach moth and in grapes to the berry moth. The larvae of the so-called fruit flies infest

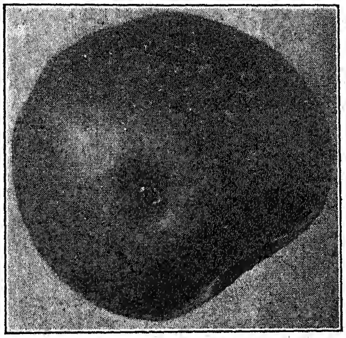


FIG. 120.—A characteristic codling moth "sting."

fruits of many kinds. Included here are the apple maggot or "railroad" worm, so named because of tunnels penetrating the flesh in every direction, the blueberry maggot, the cherry maggot,

the Mediterranean fruit fly, and many others. Characteristic tunnels of the apple maggot are shown in Fig. 119.

So-called "stings" are of many kinds and may be caused by any one of a large number of insects, including the codling moth,

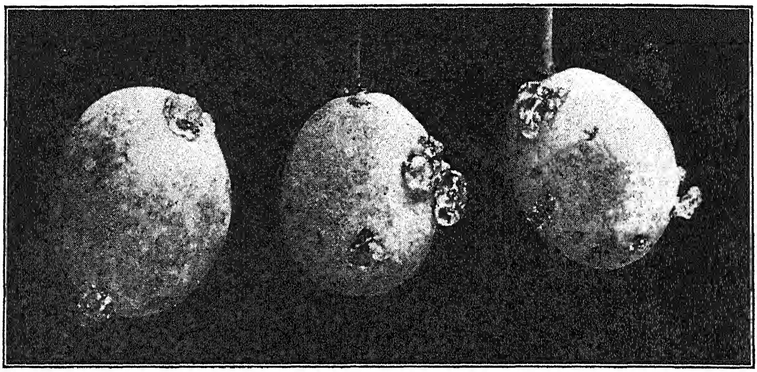


Fig. 121.—Curculio-stung plums. Note the crescent-shaped, egg-laying punctures on the right-hand specimen. Gummy exudates collect at some of these punctures.

several of the curculios, the red bugs, the Alabama peach moth and many others. More frequently than not, the surface is depressed or indented at the point where the fruit was stung. The injury is generally occasioned by a feeding or egg-laying

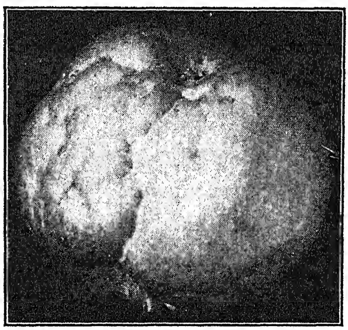


Fig. 122.—Surface roughening caused by the apple red bug.

puncture and may be little more than skin deep or it may extend to the core or pit of the fruit. Some of the more common of these blemishes are shown in Figs. 120, 121, and 122. The presence of one or two stings may not utterly ruin a fruit for the market but it always results in a lowering of its grade and value.

Blemishes of a somewhat different type than those just described are illustrated in Fig. 123. They are occasioned by

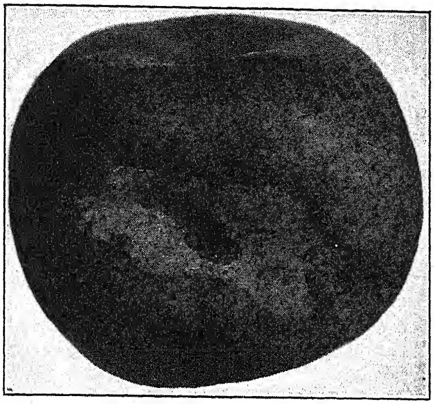


FIG. 123.—A sharp-margined, russeted area caused by the surface feeding of a chewing insect while the fruit was still very small. It is a surface blemish but may be accompanied by more or less deformity.

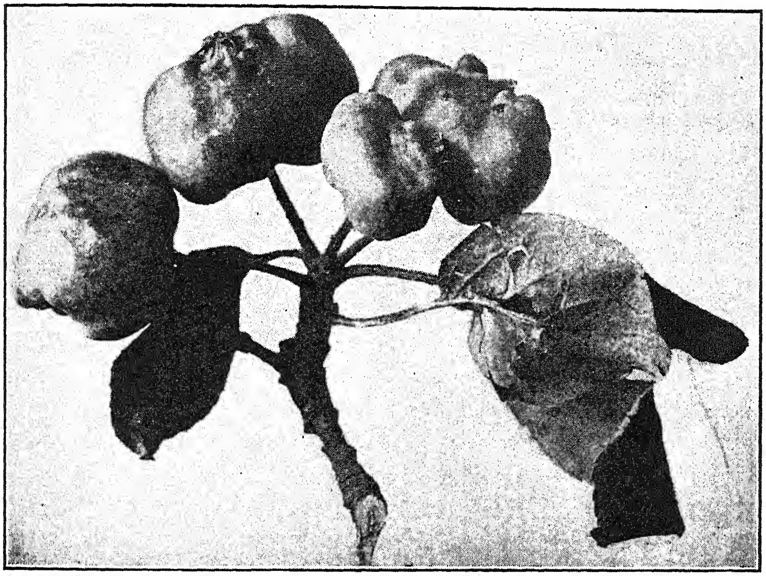


FIG. 124.—A cluster of "aphised" apples. They seldom grow much larger than the specimens shown in this picture and they cling tenaciously to the spur.

the surface feeding of certain kinds of caterpillars and other chewing insects. These surface wounds often are healed through the

formation of a rather heavy corky layer; sometimes this layer is so thin that it simply gives the affected area a russeted appearance. Russet areas due to wounds of this kind usually have clear-cut margins, while the margins of those due to spray injury or frost are less distinct. When the feeding wounds extend into the flesh they are likely to result in a more or less one-sided development of the fruit.

When aphids attack the flower cluster of the apple usually all the blossoms "set" and the resulting fruits, much dwarfed and misshapen, remain attached to their spurs until long after the usual harvesting season for the variety. A cluster of "aphised" apples is shown in Fig. 124.

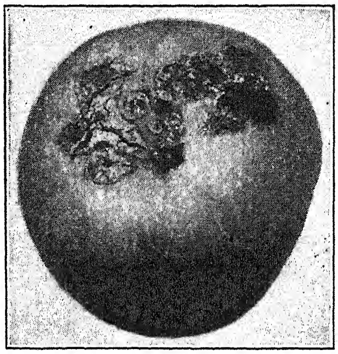


FIG. 125.—Lesions caused by the apple-scab fungus.

Scab, rust, blotch, fly speck, etc. are names given to lesions on the fruit as well as injuries to the leaf. Indeed many of the fungi which attack the foliage likewise attack the fruit. Most of the diseases grouped here cause surface blemishes only, though in cases of heavy or general infection the fruit may become somewhat misshapen and in extreme cases it may crack. Characteristic lesions of the apple-scab fungus are shown in Fig. 125.

The decay of fruit while still on the tree or shortly after picking may be due to any one of a number of fungi or bacteria. Each of these rots presents characteristics by which it may be classified, though differentiation between them may be difficult. The term black rot is applied to characteristic diseases producing black or dark decays of certain fruits, particularly apples (Fig. 126) and grapes. Bitter rot causes a soft decay of apples, accompanied by the development of a very bitter taste in the

decaying tissues. Brown rot, as the name indicates, produces a decay with a brown color. This is a soft rot and is found on many kinds of fruits, though it is particularly severe on the stone fruits. The decays just mentioned, together with a number of others, invade the living tissues of partly developed or partly matured fruits. Another large group of decay-causing organisms, many of which are classed as molds, lead to the rotting of fruits in storage or in transit. Care in picking, grading, and packing does much to reduce the decay development after harvest, largely through avoiding mechanical injuries that bruise or break the skin of the fruit and thus permit the establishment of these fungi.

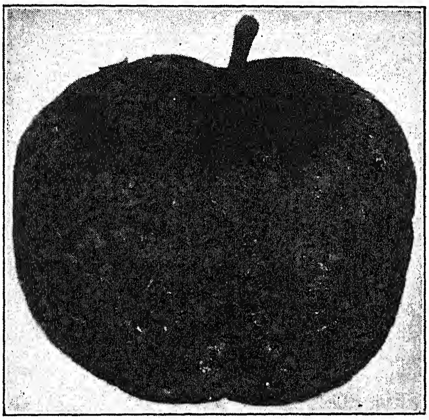


FIG. 126.—Decay caused by the black-rot fungus. Note the shrinking of the skin and the pimpled appearance, characteristic of an advanced stage of this decay. The skin, at this stage, acquires a rather leathery texture.

LIMB RUB AND SCALD

Constant rubbing against a limb or twig often causes more or less abrasion of the skin, which turns brown. This may be followed by russeting and in more severe cases by the formation of a rather thick corky protective layer at the point of injury. These wounds bear some superficial resemblance to cankers or lesions caused by fungus attack. They are found most commonly in apples and pears.

Intense sunshine, usually combined with low atmospheric humidity or high temperature or with both, may result in what is generally described as a scalding of the exposed sides of the fruits. Those on the south and southwest sides of the tree are

naturally most subject to this form of injury. In apples and pears it usually takes the form of somewhat sunken, dark, glossy areas, with more or less cork formation just beneath the surface, and is sometimes accompanied by more or less cracking (Fig. 127). In some of the berry fruits the injured tissues are generally lighter than normal in color, watery in appearance, and look more or less as though they had been scalded. Scald is mentioned here because it is often mistaken for a fungus injury. Prevention lies in the use of such cultural and pruning practices as augment and conserve the soil moisture supply, reduce transpiration, and provide at least a small amount of shade for the developing fruit.

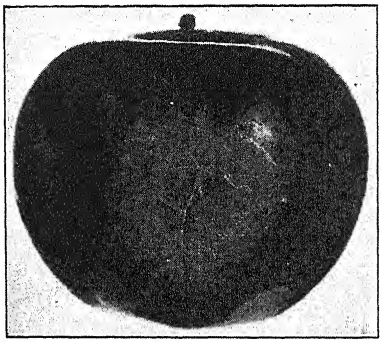


FIG. 127.—Sunburn or sunscald on the exposed side of an apple. There is usually more or less cork formation immediately under the skin, particularly where there is cracking.

Distinct from the sunscald just mentioned is storage scald. This, too, gives the fruit a scalded appearance and similarly is in no way related to insect or fungus attack. It develops mainly on the uncolored sides of apples and pears, that is, where the underlying or ground color is not masked by an overlying blush or stripe. Production methods that lead to the harvesting of poorly colored fruit and premature picking or lack of æration in storage are contributory causes.

FRUIT PIT, FRUIT SPOT, CORK, DROUGHT SPOT

These names and several others are applied to a group of disorders that apparently are more or less closely related and are found principally in the flesh of the apple, though something of a similar nature sometimes occurs in plums. These diseases are characterized by the development of brownish, rather dry,

corky spots in the flesh of the fruit, sometimes close to the surface, sometimes at the core, sometimes more or less evenly distributed throughout the flesh. The names themselves are more or less descriptive of the lesions. The exact cause or causes of these disorders are not known, though there is some reason to believe that they are generally associated with local or temporary water deficits within the plant. They are not caused by fungus or insect attack.

Surface injuries of similar appearance are also caused by hail. This injury, however, is limited to one side of the fruit.

FRUIT CRACKING

Any one of several causes may lead to cracking of some fruits. Heavy rains late in the growing season, following a long-continued drought, may cause more or less splitting, especially in stone fruits and apples. Cracks due to this cause are clean edged. No fungus or other lesions are associated with the fresh cracks, though the tissue exposed by the fracture soon becomes infected. Material reduction of cracking from this source is difficult, though sometimes improvement of cultural practices to provide a more even moisture supply helps materially. Very severe attacks of scab and of blotch cause apples and pears to crack. In these cases, of course, associated with the cracks are the lesions of the causal fungi. Under certain environmental conditions the application of either Bordeaux mixture or lime-sulphur to apples may lead to a cracking closely resembling that caused by scab or blotch.

RUSSETING

The fruits of some varieties of pears and apples are normally more or less completely russeted. This condition of the surface sometimes occurs in many other varieties that are not normally russeted. Particularly is this true during seasons or in sections of high atmospheric humidity. Russeted patches or areas on the apple and pear are sometimes caused by or at least associated with scab attacks and the surface feeding wounds of certain insects. The application of some spray materials, especially Bordeaux mixture, accentuates the trouble. In general, dusting materials produce less fruit russeting than the liquid sprays carrying the same ingredients. From this standpoint greater

care is required in the selection of spray materials for a moist than for a dry climate.

Russet bands encircling the fruit, such as that shown in Fig. 128, are due to frost during the period of fruit setting. They are more likely to occur near the apical than the basal end of the fruit and in some cases they lead to more or less deformity. In the plum russeting due to frost is more likely to be limited to irregular areas or patches than to appear in the form of a band.

Confronted with the lists of apparently possible disorders, the beginner can be pardoned for a feeling of bewilderment and dismay. Experience and study, however, rapidly simplify

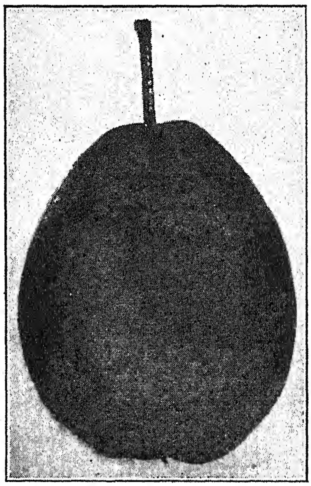


FIG. 128.—A russet band due to frost injury at or shortly after blossoming.

his acquisition of a working knowledge of the things he is likely to encounter in his own orchard. Pests have been studied carefully enough throughout the country to permit him to ascertain which are prevalent in his locality. Many disorders can be eliminated because unrecorded in his section; many others are rarely prevalent enough to be important. In short, the troubles which are unremitting and destructive in their attacks in any one orchard are comparatively few, although watch should be kept for sporadic and possibly very destructive visitations. For one locality the various contingencies may be placed in three categories: those which are reasonably sure to occur, those which may occur, and those which are not likely to occur.

CHAPTER XVII

SPRAY MATERIALS

Insect pests and fungus attacks on plants are not new. Fifteen centuries before the Christian era

". . . the locusts went up over all the land of Egypt . . . very grievous were they . . . For they covered the face of the whole earth, so that the land was darkened; and they did eat every herb of the land, and all the fruit of the trees which the hail had left; and there remained not any green thing in the trees, or in the herbs of the field, through all the land of Egypt."

Before that, Joseph had readily seen in Pharaoh's dream of "seven ears, withered, thin, and blasted with the east wind" a warning of seven years of famine. In recent years man has learned to read, in solid rock, records older still by many thousands of years, telling the story of insect and fungus attack on plants now known only through their fossil remains.

In many cases these visitations were regarded as divine punishments and efforts were made to placate the divinity offended, whether by releasing people held in bondage or by sacrificing, as some pious Romans did, to Rubigo, the rust-god. Other Romans apparently either supplemented their sacrifices by other procedures or relied entirely on different measures, for Pliny, in the first century of the Christian era, wrote:

. . . some give the name "volucre" to an insect which eats away the young grapes; to prevent this, they rub the pruning knife, every time it is sharpened, upon a beaver skin, and then prune the tree with it; it is recommended also that after the pruning, the knife should be well rubbed with the blood of a bear. Ants, too, are a great pest to trees; they are kept away, however, by smearing the trunk with red earth and tar; if a fish, too, is hung up in the vicinity of the tree, these insects will collect in that one spot. Another method, again, is to pound lupines in oil, and anoint the roots with the mixture. Many people kill both ants as well as moles with amurca, and preserve apples from caterpillars as well as from rotting, by touching the top of the tree with the gall of a green lizard . . . As for mildew, the greatest curse of all

the corn, if branches of laurel are fixed in the ground, it will pass away from the field into the branches of the laurel.

This statement by the great encyclopedist may be considered to embody the best methods known in the last days of Pompeii, though an old Syrian practice of declaring martial law at periods of pest outbreak and compelling each person actually to kill so many measures full of insects would seem somewhat more effective.

So matters stood for sixteen or seventeen centuries, or if any change in materials is to be noted during that period, it is a gradual discarding of those things that were apparently suggested by superstition and in their place a substitution of others that, because of their obvious offensiveness to man, were expected to be effective against insects. "Compounds," or "compositions" as they were usually called, of this character became not only numerous but formidable in their array of noxious ingredients. LaQuintinye, the foremost gardener of his time, advocated the treatment of cankers by "cutting to the quick" and had tried—unsuccessfully—to combat some insects by destroying their eggs, but insects and fungi were still virtually uncontrolled. As late as 1880, many orchardists in the United States were placing cloth bands around their trees, as enticements to the codling moth; these bands were visited periodically and the pupae destroyed with a stick. Curculios were being jarred from plum trees onto sheets, and then collected and destroyed. This was the method of the more ambitious orchardists; the majority did nothing.

Withal, the first concerted action against plant pests may be considered to have begun with the advent of the Colorado potato beetle. The westward spread of cultivation had made a bridge of potato fields between the native home of this beetle and the extensive potato fields of the east; across this bridge marched the insect army in the late sixties. In 1869 a farmer in Illinois found that he could preserve his potato plants by coating the tops with arsenic and still harvest edible potatoes. Application of this finding to fruit trees was slow, however, from fear lest the arsenic poison the consumer of the fruit. While the use of arsenicals was gaining ground, a discovery in France gave spraying added impetus, by indicating that it offered a means of protecting fruit and foliage against fungus attacks. The botanist Millardet, employed by the French government in vineyards around Bordeaux, noticed, in the midst of the general devastation, a few

healthy vines which still possessed foliage and fruit. The owner, as a protection against another blight—thieves—had sprinkled some vines near the highway with a mixture of lime, bluestone (copper sulphate), and water. Unconsciously he had hit upon a protection against a greater source of loss—fungus diseases. With some modification, this material was tried by Millardet and announced to the world; as Bordeaux mixture it is still in use. With it the present use of fungicides really began.

SPRAYING MATERIALS CLASSIFIED

Spray materials fall into two groups, in accordance with the nature of the pests they are intended to control; those used to kill insects are termed insecticides and those used against fungous diseases are known as fungicides. In some cases one material does double duty. On apples lime-sulphur is used as a fungicide in the summer and an insecticide in the dormant season; on peaches, however, the dormant application is both fungicide and insecticide simultaneously. Generally, however, a material is one or the other.

Insects may be grouped, for practical purposes, even if rather unscientifically, into two classes, the biting or chewing and the sucking. The biting insects bite whole sections of a leaf or fruit and eat them away; "caterpillars" in general exemplify this type of work. Since they eat the plant material their control is effected by so distributing poisonous material that as they eat the leaf they get with each mouthful a little poison and soon their wonted haunts know them no more. In general, they are rather easily controlled. Sucking insects are not affected by the poisonous coating on leaf or fruit or bark for they penetrate deeper and suck the juices of the plant. They may be killed in various ways: (1) by affecting the breathing apparatus, as is done when soap solutions or oily preparations are applied, (2) by sealing the insect in position and depriving it of oxygen, as happens when concentrated lime-sulphur is used against San José scale, (3) by lethal gas, as when nicotine is used, paralyzing the nerve centers.

The poisons used against biting insects are known as stomach poisons, since they act only when taken into the stomach. If they adhere well to the foliage and fruit, they may be applied before the insect arrives and still be effective when needed. The controls for sucking insects, however, can be used only when the pest is present and must come in close contact with the insect

rather than with the foliage or fruit or bark; hence they are known as contact insecticides. Proper timing of their application is likely to involve close discrimination.

THE ARSENICAL SPRAYS

Practically all the stomach poisons in common use contain arsenic. In the early days of orchard spraying, Paris green, a combination of arsenic and copper, was the favored material. The rapid increase in use of this arsenical, particularly when Massachusetts began an extensive struggle against the gypsy moth, led to such increases in price that the Massachusetts Experiment Station brought out a cheaper substitute, arsenate of lead. In this case the substitute is an improvement on the original material; it adheres better to the plant, it causes less burning, and for most chewing insects that infest the orchard its killing power is adequate. After a time, however, demand overtook supply and the appearance of the cotton planter as a user of arsenicals for a time raised the price of this material. Another and cheaper substitute, calcium arsenate, has been offered. As a dusting material this seems satisfactory; its killing power is rather greater than that of arsenate of lead, but applied as a spray to fruit trees it has resulted in more injury to foliage and fruit and its adhesiveness is lower. Improved methods of manufacture may provide a better calcium arsenate as they have improved the present lead arsenate over that first used, but at present it cannot be considered equal to arsenate of lead for general orchard use.

Arsenate of lead is sold both in powder and in paste form, the paste containing about 50 per cent, by weight, of water. It is soluble in water to only a very slight extent, stays well in suspension, adheres tenaciously to foliage and fruit and may be mixed with most of the important spray materials. There are many commercial brands on the market, differing in physical condition—texture, size of particle, fluffiness, and the like—and in chemical composition. Those brands that are very finely divided, "fluffy," and remain longest in suspension are preferable if they are of the proper composition. The so-called acid arsenates contain somewhat more arsenic than the neutral and basic types, and they kill more quickly and are preferable under many conditions. They are, however, more reactive with other spray

materials with which they may be mixed and consequently are more likely to cause spray injury on plants susceptible to this type of injury. The common "arsenate of lead" is acid. The strength at which arsenate of lead is used varies according to the kind of pest to be controlled, and to some extent according to the plant to which it is applied. The ordinary concentration, however, for use with orchard fruits is 2 pounds of the powder (or 4 pounds of the paste) to 100 gallons of spray.

THE OIL SPRAYS

It has long been known that oils of many kinds kill insects. Mineral oils are particularly effective. The oil must come in contact with the body of the insect to destroy it, while the arsenical poisons must be actually eaten to be effective. Consequently oil sprays may be used for those insects which, having sucking mouth parts, cannot be contolled by stomach poisons. They are, of course, equally effective against some of the chewing insects that may happen to be present at the time but since they are considerably more expensive than the arsenicals they are seldom employed as substitutes for stomach poisons. Among the first of the mineral oils to be tried rather extensively as a contact insecticide was kerosene. Used alone it not only destroyed all the insects with which it came into contact but it was almost equally effective in killing the fruit plants. It proved dangerous even to the trunks and limbs of trees. Finally, however, ways were found of so mixing it with soap that it could be diluted with water. When properly made and sufficiently diluted this emulsion is effective against sucking insects and harmless to some plants. The difficulty of securing proper preparation, however, for a long time proved a serious obstacle to the successful use of oil sprays and has caused abandonment of kerosene. In many cases the use of hard water, though unavoidable, virtually prevented proper emulsification and resulted in serious injury. The oils themselves were very variable, even under one trade brand. For 30 years after the first trials, oil sprays were regarded with considerable suspicion and were not generally employed in the orchard, though there was no doubt about their insecticidal value.

With the later introduction of standard brands of so-called "miscible oils" (in effect, factory-prepared combinations of oil,

soap, water, and sometimes other ingredients), that needed only dilution with water before they were applied to the tree, confidence in sprays of this class grew, and their use has gradually extended until at present they have a recognized standing. The difference in dilution of the various proprietary brands has a wide range, depending on the material and sometimes on the pest; San José scale succumbs to a 2 per cent emulsion, while leaf roller control requires 6 per cent.

More recently several formulae for the home preparation of so-called lubricating-oil emulsions have come into rather wide use. The preparation of these emulsions places somewhat more labor on the grower, but they are cheap and relatively stable. Their principal usefulness is in the late dormant season applications to control scale insects and they provide the best means of controlling mites, red spider, and leaf roller.

Numerous lubricating-oil emulsions are rather commonly employed. A fairly typical recipe uses: oil, 6 gallons; copper sulphate, ¾ pound; lump lime, ¾ pound (or hydrated lime, 1½ pound); water, with the copper sulphate and lime, to make 3 gallons. The copper sulphate is dissolved in the water, the lime is added, and the mixture is stirred and then poured into the oil. The sprayer is utilized to emulsify the mixture, which is repeatedly pumped back upon itself under high pressure through the nozzle of the spray gun. The quantities as stated make a stock emulsion sufficient, when diluted, to make 200 gallons of 3 per cent material ready for spraying. For actual spraying the tank is filled with water and the stock emulsion is pumped into it through the gun. The term "3 per cent lubricating-oil spray" applied to this material refers to its oil content.

In all fairness it should be stated that there are more chances of mishap in the use of oil sprays than there are with the other common spray materials. Men who are slovenly workmen should never be encouraged to use them and occasionally their apparent capriciousness baffles the best.

In the earlier days of spraying with oil emulsions, these materials, when used at all, were employed in dormant-season applications against scale insects and likewise for summer applications against aphids and other soft-bodied sucking insects. More recently their use has been rather restricted to dormant-season spraying and to the delayed-dormant spray, a treatment applied between the dormant and growing seasons.

NICOTINE SPRAYS

Among the numerous materials of organic origin used as repellants or contact insecticides early in the development of spraying, tobacco alone has steadily increased in importance. For many years tobacco sprays were prepared by the grower from tobacco stems steeped in water just before the spray was applied. The cumbersomeness of this method discouraged the general use of tobacco in large-scale orchard operations until concentrated extracts, requiring only dilution with water before application, became available. These are offered under a variety of trade names. Most of those now in use are 40 per cent solutions of nicotine sulphate. They are diluted at the rate of 1 pint to 100 gallons of water when employed against aphids and similar soft-bodied sucking insects. In the application of most contact insecticides, the spray must actually touch the insect to kill it. With nicotine sprays this is desirable but not always necessary, since, under favorable conditions, particularly as regards temperature, nicotine fumes liberated from the solution act as a poison gas. In either case application should be thorough, for the spray or its fumes must reach the insect; the insect will not come to the poison and eat it, as in the case of arsenicals.

In recent years nicotine-impregnated dusts have been extensively used against certain insect pests. These dusts usually contain from 1 to 3 or 4 per cent nicotine sulphate mixed with some carrier, such as kaolin, dolomite, or hydrated lime. Their efficacy depends less on their actual nicotine content or on the actual contact of the material with the insect than on the readiness with which nicotine fumes are liberated by the carrier. Much depends on the nature of the carrier, therefore, and on the temperature prevailing at the time the dusting is done. Relatively high temperatures favor quick killing. Nicotine "carriers" that are satisfactory in a hot climate or for midsummer use may not be equally satisfactory in a cooler climate or season.

To make the enumerations of common insecticides complete, mention should be made of lime-sulphur. This material is used as a "dormant spray," (applied during the dormant season) or delayed dormant, against scale insects, but since it is used more widely to combat fungi, it is discussed among the fungicides.

THE FUNGICIDES

Fungi are minute plants which lack the green coloring matter that enables other plants to manufacture their own food material. In consequence they must live parasitically on other plants or otherwise feed on dead plant or animal material. The molds that grow on stale bread or cheese and the mildews that appear on leather are familiar examples of fungi. The fruit grower is interested in the particular fungi that attack fruit and fruit plants, sending thread-like branches into the very cells to obtain food. Some kinds of fungi may do no more harm than to disfigure the fruit and make it commercially valueless; other kinds may destroy an entire branch or cause the death of a whole tree.

The apple scab fungus lives over winter in a dormant state in dead apple leaves; in the spring, with the proper combination of moisture and temperature, its spore sacs burst and spores are discharged. These are carried about by air currents and some of them lodge on an opening bud, or leaf, or blossom, or fruit of the apple. With suitable conditions as to moisture and temperature these spores, like seeds, germinate and send out microscopic hair-like growths that penetrate the tissues of the host plant. Here they branch and extend themselves, perhaps breaking out through the skin, finally forming more spores which are discharged into the air to infect the host plant at some other point.

Like the higher plants, fungi are most tender in the germinating stage and are most easily destroyed then. Once they have penetrated into the host plant they are beyond control but if the proper poisonous material covers the surface of the host germination of the spores will be inhibited or, when the spores germinate, they will be killed. Fungicides must therefore be applied before infection occurs. With insecticides this caution is not always essential; with fungicides it is invariable.

THE COPPER SPRAYS

The fungicidal value of copper sulphate was recognized over a century ago but inability to use it in controlling fungi without also injuring the host plants prevented its use until the early eighties. The story of the discovery of Bordeaux mixture, a fungicide in which copper is the active ingredient, is well known. The formula worked out by Millardet is, with slight changes, in use today

and Bordeaux mixture is recognized as one of the most effective, if not the best, of fungicides. The differences in the Bordeaux mixtures prepared according to various formulæ consist principally in the concentration of the copper-containing compounds or in the surplus of the supposedly inert lime. A useful formula calls for 4 pounds of copper sulphate, 6 pounds of lump or stone lime (or 9 of hydrated lime), and 50 gallons of water. In technical jargon this is called a 4–6–50 (or 8–12–100) Bordeaux. It may be prepared by dissolving the copper sulphate in water (usually making a stock solution containing one pound of the chemical in one gallon of water), slacking the lime so as to obtain a "milk" of similar concentration, and then pouring the requisite amounts of the two stock preparations into the spray tank after filling it with nearly the full amount of water that is required.

Bordeaux mixture is one of the few commonly used spray materials which the grower should himself prepare. Most of the others simply require dilution with a proper amount of water. Even Bordeaux is available in a number of commercially manufactured powders or pastes which require dilution only, but these preparations are comparatively expensive and for most purposes home mixing of the ingredients is common.

Bordeaux mixture has never been successful as a spray for peaches or Japanese plums because of the tenderness of their foliage, and on the apple it causes an inordinate amount of russeting in the fruit. It has, for this reason, been supplanted in some schedules, but it remains the best fungicide for many crop plants, among them the grape and the pear. It is preferable to lime-sulphur, the other leading fungicide, on pears because it injures the foliage less and for summer sprays on apples in some sections because it controls blotch more effectively. In very hot weather it injures apple foliage little or none, while lime-sulphur under the same conditions may cause considerable damage.

The use of copper-containing dusts in the orchard has never reached large proportions. Dehydrated or monohydrated copper-sulphate dust, mixed with some carrier, *e.g.*, hydrated lime, is used to a limited extent.

THE SULPHUR SPRAYS

Sulphur, in one form or another, but principally as flour or flowers of sulphur, has probably been employed longer than any other material, excepting nicotine, now in common use, as a

remedy for insects and diseases. The early reports of its use leave considerable doubt as to whether it was applied principally as an insecticide or a fungicide, though Thomas Andrew Knight used it apparently to control peach-leaf curl early in the nineteenth century and in the middle of that century sulphur dust was used in French vineyards, clearly as a fungicide. Some of the early writers recommended its use alone, dusted on plants, while others suggested that it be mixed with lime or ashes or stirred with soap suds and applied in liquid form. Many of the earlier spraying formulæ which included a large number of ingredients, the virtue of which apparently lay in their noxious character, probably owed most of their effectiveness to sulphur. Its use as a dust to prevent mildew on grapes is of long standing in California and the practice of placing it on the heating pipes of greenhouses to check rose mildew is almost as old as the use of heating pipes in greenhouses. At present sulphur is perhaps the most important material for fungicidal use in the orchard, entering into the composition of several fungicides.

Lime-sulphur is perhaps the most widely employed of all fungicides, since it is used extensively on the apple, the most widely grown fruit. It contains compounds of sulphur in solution and is strongly caustic, as experience quickly demonstrates to the open eye. For this reason it must be diluted for use on foliage and it cannot be employed, even when diluted, on peach or Japanese plum foliage; it injures grape, pear, raspberry, and potato foliage. The dormant spray for scale insects is applied during the dormant season, not because the insects are more susceptible at that period, but because that is the only time when a solution strong enough to kill them can be used without injuring foliage. Peach leaf curl, however, is controllable only during the dormant season since the buds are invaded by the fungus very early in the spring and spraying at any strength after infection has once taken place would be futile.

Most fruit growers purchase prepared lime-sulphur in concentrated form, since its manufacture is not particularly easy with the equipment available on most farms and the composition of the home-made material is fully as variable as that of the proprietary brands. It may be made from these ingredients: sulphur, 100 pounds; stone (lump) lime, 50 pounds; water, 50 gallons. Manufacture begins with slaking some of the lime, using no more water at first than the slaking lime will keep warm.

Sulphur, lime, and water are then added, in small quantities, in rotation; the completed mixture is boiled for about 1 hour. The resulting liquid, after the sediment has settled, is clear, deep amber in color, and usually has a specific gravity of 30° to 35° on the Baumé scale. This is the "concentrated" stock solution commonly sold.

For orchard use the concentrated solution is diluted. Seven to ten gallons of water with each gallon of the concentrated stock solution make the material used in dormant season applications and for summer use to each gallon is added between 30 and 40 gallons of water, the exact dilution depending on the concentration of the stock solution. In other terms, the formula just given provides a stock solution sufficient, when properly diluted, to make about 500 gallons of material for the dormant spray or 1,500 gallons for summer use.

For dusting, sulphur has been the principal fungicide used. Chemically pure flour of sulphur, regardless of the fineness of the particles, does not make a satisfactory material for dusting, because of the tendency of the particles to adhere to one another and thus to form agglomerations large enough to interfere with proper delivery and distribution on the tree. This difficulty is obviated by the admixture of one of several materials called "fluffers;" the so-called "pure" sulphur as sold for dusting purposes, contains a small percentage of "fluffer." Fineness of the particles is indicated in terms of the number of meshes per inch in a bolting cloth, actual or theoretical, through which it would pass, it varies from 200 to 5,000. The coarser particles, *i.e.*, those in the 200- to 700-mesh class, are of doubtful fungicidal value, but a 200-mesh sulphur contains a very large proportion of particles much finer than the indicated maximum.

Mixed with arsenate of lead powder, sulphur constitutes the "90–10" combined insecticide and fungicide rather commonly used on apples. The tenderness of peach foliage leads to the addition of lime to the mixture and the standard combined dust for this fruit is an "80–10–10," though 80–5–15 is recommended occasionally. In formulæ embracing these ingredients, the proportions by weight are stated in this order: sulphur, arsenate of lead, and lime. Most of the proprietary mixtures contain sulphur and arsenic.

Sulphur dusts can be used on foliage too tender for lime-sulphur sprays, and even in fruits whose foliage is tolerant of the

spray the finish of the dusted fruit is often superior to that which has been sprayed. Dusted fruits are not, however, popular with pickers and have sometimes made difficult the retention of a harvesting crew.

Dry-mix or dry-mix sulphur-lime has been used chiefly on fruits whose foliage is injured by lime-sulphur, particularly on peaches and Japanese plums. Its eligibility for use on tender foliage is due to the presence of sulphur in suspension rather than in solution. For a long time the difficulty of carrying sulphur in water suspension seemed insurmountable because of the "unwettable" nature of sulphur and the cumbersome, now superseded, self-boiled lime-sulphur was the only fungicide available where Bordeaux or lime-sulphur could not be used. If, however, calcium caseinate is thoroughly mixed with sulphur, the mixture can be suspended in water very readily. This property of calcium caseinate is utilized in the dry-mix sulphur-lime, which is made from these materials: sulphur, 16 pounds; hydrated lime, 8 pounds; calcium caseinate, 1 pound. The three ingredients are thoroughly mixed, then stirred into a thin paste with water and finally diluted with water to make 100 gallons. Sometimes, when this spray is to be applied just before harvest, the hydrated lime is omitted, to avoid leaving any conspicuous residue on the fruit.

Dry-mix sulphur-lime should not be confused with dry lime-sulphur, which is a standard lime-sulphur, to which a small quantity of some "stabilizer" has been added in solid form.

OTHER MATERIALS

Materials other than those already discussed are occasionally used in orchard spraying. The so-called spreaders have no fungicidal or insecticidal value of their own, but mixed with other materials make them spread more evenly and adhere better. These are for the most part casein compounds. There is considerable difference of opinion as to their value. Certain sulphides, particularly those of potassium and iron, are occasionally used against mildew. These are of secondary importance, however.

Wood borers, which pass their feeding stage within the plant and do not feed on its exterior, are not controlled by ordinary spray applications. In fact the use of an insecticide—and this

is not a spraying material—is feasible against only one of them; this, fortunately, is the most destructive in the orchard, namely, the peach borer. Since the eggs are laid on the bark, near the surface of the soil, the young larva is susceptible to attack. This is accomplished by spreading on the ground in early September an ounce of paradichlorobenzene (known commercially as P.D.B. or Krystal gas) in a ring surrounding the tree, but 2 inches from it. The gas volatilized from this material kills borers. To prevent too rapid volatilization and escape of this gas, a mound of earth is raised around the tree, kept there for a month and then removed. It should, however, be replaced with a fresh mound before cold weather sets in, to prevent winter killing of the bark, which is likely to be tender, because of its exclusion from atmospheric influences. Use of this material on trees under 4 years of age is not without danger, though it is frequently successful.

Another material in rather common use in some parts of the country that classes neither as a fungicide nor as a stomach or contact poison but is nevertheless effective against the attacks of certain insects goes under the trade name of tree tanglefoot. It is an extremely sticky compound that serves as a repellent. Narrow bands of this material placed around tree trunks prevent injury from climbing cutworms. The same material is used in vineyards to band both vine trunks and trellis posts.

The present list of materials used for orchard spraying and dusting has been evolved after considerable trial and error, but cannot be regarded as permanent. No material in use today can be considered ideal for all or even most of the many purposes and pests for which it is used. Nicotine sulphate is relatively too expensive; commercial lime-sulphur preparations cause too much burning of foliage or russeting, dropping, or dwarfing of fruit; lead arsenate does not give satisfactory control of curculio. Many factors affect the usefulness of any material. Above all, it must be effective, it must not seriously injure the host plant, it must not affect the salability of the fruit, it must adhere well, and it must be reasonably cheap. Price is subject to wide fluctuations. A new pest may increase the use and affect the price. Because some of the materials used are by-products of chemical manufacture, changes in other industries are likely to have their effect. The electrical industries, through their enormous consumption of copper, have been effective in causing

a relative abundance of arsenic, which is obtained as a by-product in copper smelting. Similar changes in some other industry might make available other materials not now considered because of price. Prices fluctuate from year to year. Beyond all this, however, price is not the only consideration; the cost of application varies also. The alert grower may find himself shifting from one material to another and perhaps back again, as circumstances change. Indeed, much of the changing from dust to spray applications, or vice versa, has been due to variations in the relative costs of materials and of the labor of applying them or to ability to cover a given acreage within the time limit during which coverage is critical. Whatever material is used, excepting the contact insecticides and whatever may be the method of application, however, the cardinal principle underlying its use will be "save the surface and you save all."

CHAPTER XVIII

SPRAYING SCHEDULES

With the coming of spring a wave of reawakening vegetation moves northward at a rate which averages 10 to 15 miles a day. This rate varies, however, with local conditions such as altitude, proximity to large bodies of water, and relative amounts of cloudiness, and the wave may flow by large isolated areas where vegetation is still dormant. So wide are the differences in plant development at one time within the United States, that Florida starts shipping strawberries before the coldest weather sets in through the northern states, and California sometimes ships ripe cherries while the cherry orchards of northern Michigan are in bloom.

With the wave of opening buds progresses another wave—of revivified pests. Insects and fungi, too, respond to the returning spring. To control these pests resort is had to the use of certain spray materials or combinations of spray materials whose applications are timed with reference to vulnerable points in the life histories of the parasites. The combination of spray treatments recommended for a particular kind of fruit is formulated in its spray schedule, which is essentially a set of rules telling when spray applications should be made and what materials should be used. These various schedules are based on the assumption that every year all of the more, and many of the less, important pests will be present to an injurious extent. They assume also that each year the same pests will appear at the same time and cause about the same amount of trouble if left unchecked. These assumptions, however, are not altogether warranted, for there is great variation from season to season and from place to place in the seriousness of particular pests and particular diseases. For example, the codling moth may be making its nocturnal visits to southern apples before the buds have well started in northern orchards and scab spores may be discharged in the Ozarks while in New England the leaves in which the fungus spends the winter are still buried in snow. The Connecticut

peach grower may be applying the dormant spray to control leaf curl while the Georgia peach grower is fighting curculio and brown rot. The nation may unitedly observe Mother's Day or raisin week, but it could hardly unite on a single codling moth day or brown rot week. There is, then, no possibility of assigning uniform dates for spray treatments throughout the United States.

Many states, even, are so large and so varied in their topography that a uniform date for a particular spray throughout the state is impracticable. For example, the difference in the blossoming date along the east shore of Lake Michigan may amount to two or three weeks, and within several New York counties along the Lake Ontario shore pronounced differences occur within a few miles. In mountainous regions, east and west, differences in altitude make considerable differences in time of blossoming. Even at the same spot the blossoming date varies considerably from year to year; the Elberta peach has bloomed in an orchard at Columbia, Missouri, as early as Mar. 15 and as late as Apr. 17.

These variations necessitate the use of the trees themselves, rather than the calendar, as the guide to the proper time for applying spray treatments. Arsenate of lead applied to a Maine apple orchard when the petals are dropping in Virginia would be wasted; it could not, at this time, cover the tissues on which the codling moth larva feeds, because the buds would still be closed. If, however, apple growers everywhere follow the rule of applying the arsenate of lead when the petals are dropping from the blossoms, they will hit upon the proper time, regardless of locality or season. The spraying schedule, then, is really a schedule and not a "calendar" of spraying operations.

FACTORS DETERMINING THE GENERAL CHARACTER OF THE SPRAY SCHEDULE

The pests themselves vary in their prevalence. Apple tree anthracnose necessitates special spraying treatments in some sections of the Pacific Northwest; it is unknown in eastern orchards. Blotch is the most serious fungous pest of the apple along the Ohio River; the majority of apple growers a day's journey to the north have never seen it. Black rot, a common disease of the fruit of the apple in Illinois, works on branches,

but rarely on the fruit, in Michigan. New Mexico orchards may be visited by four or five broods of the codling moth in one season while Maine orchards in some years see only one and a partial second; many New England fruit growers control this pest better with two sprays than those of Colorado with five or six. In the Coos Bay district of Oregon apples are never infested with codling moth because the nights are too cool for the moths to fly but away from the coast this pest finds congenial conditions. Enough variations of this sort occur to make a schedule of spray treatments vary, not alone in time but also in the number and the nature of the treatments. This explains why the spray schedules that are recommended for use with a particular kind of fruit within a single state or district are in many cases accompanied by a paragraph or two of comment on modification to meet local conditions. It explains also why rigid adherence to a particular schedule sometimes gives good results in one case and poor results in another.

At least 59 apple diseases caused by fungi have been found in the United States; of the pear, a much less extensively grown fruit, the known fungus diseases number 39. In all probability as time goes on more will be found. Many of these are not serious or common enough to warrant special attention; some cannot be controlled by spraying, and many are more or less localized. With all eliminations made, however, there remains a rather formidable array of insects and fungi against which provision must be made by spraying. The accompanying complete spray schedule for Michigan apple orchards enumerates nine pests, eight insects, and one fungus; the corresponding schedule for Missouri enumerates thirteen pests, seven insects and six fungi. Some of these items are group classifications; a detailed tabulation would increase the number somewhat.

COMBINATION SPRAYS

Control of some of these pests requires more than one spraying a season; four sprays are recommended to control codling moth and six for scab in Michigan, and in Missouri four for blotch. Tabulation shows that, if all the pests were combated separately, each tree would be sprayed 20 times each season in Michigan and about 40 times in Missouri. Fortunately some applications perform double duty. The arsenate of lead applied to control cod-

ling moth also checks the canker worm and the late Bordeaux application to control blotch also takes care of the sooty blotch. Therefore the complete Michigan schedule actually calls for ten insecticide applications and six of fungicide, while the Missouri schedule indicates 10 insecticide and 7 fungicide applications.

These are, in actual practice, combined further. For the "calyx" spray of the Michigan schedule, for example, in the tank with the solution of lime-sulphur may be placed the arsenate of lead and if necessary the nicotine sulphate. The one tankful as sprayed out, then, contains three materials—one fungicide, and two insecticides. The amount of water is not increased with the addition of new ingredients; the 97½ gallons of water that are mixed with the 2½ pounds of lime-sulphur also carry the 2 pounds of arsenate of lead, and the pint of nicotine indicated. Similar combinations are possible throughout this schedule, and the total sprayings necessary for the complete schedule number only seven in Michigan and seven in Missouri. In a few cases, incompatability precludes some combinations, but schedules are adjusted to meet these conditions.

FITTING THE SPRAY SCHEDULE TO LOCAL CONDITIONS

In fitting the various schedules to his own orchard the fruit grower may save some money or lose a considerable amount. The schedules are based on the assumption that all the pests enumerated are present and injuriously active in every orchard every year. Actually this is not the case. Red bug is not of widespread occurrence, but it may become serious where it exists, or it may spread into new territory. The seriousness of aphid infestation varies greatly from year to year. If aphids do not happen to be numerous, the omission of nicotine from the early application will not lead to serious damage, but only too frequently this omission has been followed by the ruin of half the crop (Fig. 124). In fact, the seriousness of infestation of most pests varies greatly. In some years the pre-pink application for scab can be omitted. Cases like this challenge the fruit grower's skill and judgment. To use the dormant spray on apple or pear trees when it is not actually required increases the cost of producing an average crop at least 2 cents per bushel without any compensating return. Nevertheless, many growers make this application because they regard the published schedule as a set of

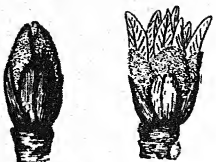
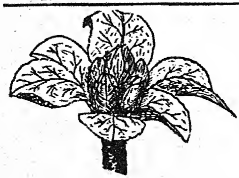
rigid and unvarying rules. To the uninitiated 2 cents per bushel may seem a small item, but seasoned fruit growers regard it respectfully. The seriousness of some pest infestations can be foretold considerably in advance; the need of a dormant spray application in March can be determined in the previous November. Others cannot be predicted as surely and it may be found in September that some treatment scheduled for the previous August should not have been omitted or that it was applied a week late. In some cases very nice judgment is required; a very wet spring usually brings abundance of early scab infection, while light early infection accompanies a very dry spring. In the one case spraying is clearly necessary; in the other the saving effected by omitting an application of spray material may justify taking a chance.

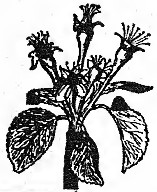
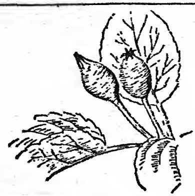
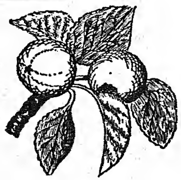
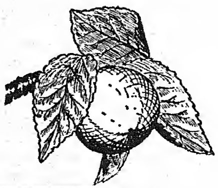
Besides weather, varietal peculiarities should be considered. Oldenburg, McIntosh, Northern Spy, and Fameuse are among the varieties notoriously susceptible to scab; some other varieties, such as Grimes and Baldwin, are much less susceptible. In some regions Baldwin, however, seems to be particularly susceptible to attack by the larva of the late brood of the codling moth. The Green Gage plum is singularly lacking in resistance to brown rot. Peculiarities such as these must be recognized and considered in any modification of the spray schedule.

In any case the certain saving in spray material and in labor resulting from the omission of any ingredient or any application must be balanced against the probability and amount of the possible loss. Nowhere in the orchardist's management is keener judgment needed and nowhere can his knowledge and experience be more profitable to him than in his spraying, but nowhere can he lose money so easily by a mistake and unless he has both experience and knowledge he is safer in following the schedule, even if it is rather expensive. It would be folly to carry fire insurance on a fireproof building, but good management to insure a building that is not fireproof, even though the fire is not expected or desired. Similarly, it may be good business not to spray for a pest which has not been prevalent and seems unlikely to appear in serious numbers, but assumption that a pest which was prevalent last year will not be serious this year must be founded on something besides hope or fond desire.

In one respect the schedules should be followed rigidly; this is in the timing of the applications. They are not infallible, but

Michigan Spray Schedule for Apples

Stage of growth	Application	Materials	To control	Explanations
	1. Dormant. Apply as late as advisable before growth begins.	Liquid lime-sulphur, 12½ gallons in 100.	Scale insects.	Should be made only when scale insects are present.
	OR			
	1a. Delayed dormant. Apply in the period beginning when the buds show silvery and ending when the leaves stick out from fruit-buds like "squirrel's ears."	Liquid lime-sulphur 12½ gallons in 100 plus nicotine sulphate (40 per cent), 1 pint in 100 gallons.	Aphids (plant lice) and scale insects.	This application should be made when aphids are present or infestation is expected. It will also control scale insects. Very thorough spraying is necessary to control aphids. Every aphid must be hit to be killed.
	2. Pre-pink. Apply soon after the delayed dormant stage. Begin soon after the "squirrel's ear" stage and finish not later than when leaves turn back from buds. (Ideal stage shown at left.)	Liquid lime-sulphur, 2½ gallons in 100, or Bordeaux (see supplementary instructions for apples).	Apple scab.	This application is very important on many varieties for the control of scab.
		Lead arsenate powder, 2 pounds in 100 gallons.	Bud-moth.	Lead arsenate should be added if bud-moth is present.
	3. Pink (cluster stage). Apply as soon as blossom buds separate in the cluster and finish before the blossoms open.	Liquid lime-sulphur, 2½ gallons in 100, plus lead arsenate powder, 2 pounds in 100 gallons.	Apple scab, bud-moth, green fruit-worm, canker-worm and other chewing insects.	This is one of the most important applications for the control of scab.
		Nicotine sulphate (40 per cent), 1 pint in 100 gallons, if needed for aphids or red-bug.	Red bug (dark). Aphis.	If red bug (dark form) is present in numbers add nicotine at this time. This will also kill any aphids not killed by the delayed dormant application.

	4. Calyx (petal fall). Should be made when most of the petals are off.	Liquid lime-sulphur, 2½ gallons in 100, plus lead arsenate powder, 2 to 3 pounds in 100 gallons.	Scab, codling-moth, and other chewing insects.	This should be completed as soon as possible after the blooming period to give greatest protection against scab.
		Nicotine sulphate (40 per cent) 1 pint in 100 gallons, if needed for red bug.	Red bug (both species).	This is the best time to kill red-bug.
	5. Ten day or two weeks. Spraying should be completed 2 weeks after petals have fallen.	Liquid lime-sulphur, 2½ gallons in 100, plus lead arsenate powder, 2 to 3 pounds in 100 gallons.	Codling moth, scab, and lesser apple worm.	Experienced growers may delay *this application* 1 to 2 weeks, depending upon weather conditions and the previous control of scab. Most growers will do well to begin it on the tenth day.
	6. Thirty day. Should be completed 30 days after the petals have fallen.	Liquid lime-sulphur, 2½ gallons in 100, plus lead arsenate powder, 3 pounds in 100 gallons.	Codling moth and scab.	In some seasons this application may be omitted. This must be determined according to the season and prevalence of codling moth.
	7. Second brood. Exact time to be determined each year, usually about the first week in August.	Liquid lime-sulphur, 2½ gallons in 100, plus lead arsenate powder, 3 pounds in 100 gallons.	Codling moth and scab.	The time of this application is determined by the emergence of the first brood moths. Official announcement is made by the entomologist, through the county agents.

MISSOURI SPRAY SCHEDULE FOR APPLES

Number and name of spray and when to apply	For control of	What to use
(1) Dormant or delayed dormant. Any time after the leaves drop in the fall and until the blossom buds begin to open in the spring. Generally most satisfactory just as buds are swelling.	San José scale and other scale insects.	Lime-sulphur 1 to 7, or lubricating oil emulsions, cold or boiled oil soap emulsion, 1½ to 50. Proprietary miscible oils at dilution marked on containers.
Special spray. When buds are opening and aphid eggs are hatching.	Plant lice (aphids). Only when serious.	Oil emulsion 1½ to 50, or nicotine sulphate ¾ pint in 100 gallons lime-sulphur, diluted 1½ gallons to 50.
(2) First summer spray (cluster bud). When individual flower buds in the cluster begin to separate, but before they open.	Plant lice (aphids), apple scab, leaf spot, curculio, canker worm.	Lime-sulphur 1½ to 50 plus 1 pound arsenate of lead. When aphids are abundant, add nicotine sulphate ¾ pint to 100 gallons of spray mixture.
(3) Second summer spray (calyx). Start when bloom is two-thirds off and finish before the blossom ends close. Most important single summer spray. Should be applied within a week after petals fall to be most effective.	Codling moth, plant lice (aphids), apple scab, leaf spot, curculio, canker worm, lesser apple worm.	Lime-sulphur 1¼ to 50 plus 1 pound arsenate of lead. When aphids are serious, add nicotine sulphate ¾ pint to 100 gallons spray mixture. On account of danger of injury to fruit, Bordeaux should not be used earlier than 12 to 14 days after the calyx spray.
(4) Third summer spray. Within 12 to 14 days after calyx spray. (If curculio injury is severe, apply within 6 or 7 days after calyx spray, using lime-sulphur 1¼ to 50 and 1½ pounds arsenate of lead.)	Apple blotch, curculio, codling moth, lesser apple worm, apple scab, leaf spot, phoma spot.	Lime-sulphur 1¼ to 50 plus 1 pound arsenate of lead. Where apple blotch or phoma spot is serious, use Bordeaux mixture (3–4–50) instead of lime-sulphur.
(5) Fourth summer spray. Apply 12 to 14 days after the preceding summer spray, or No. 4.	Apple blotch, curculio, codling moth, lesser apple worm, sooty blotch, phoma spot.	Lime-sulphur 1¼ to 50 plus 1 pound arsenate of lead. If apple blotch or phoma spot is serious, use Bordeaux (3–4–50) instead of lime-sulphur.
(6) Fifth summer spray. Apply about 12 to 14 days after No. 5.	Codling moth, lesser apple worm, apple blotch, bitter rot, sooty blotch, curculio, phoma spot.	Lime-sulphur 1 to 50 plus 1 pound arsenate of lead. If apple blotch, bitter rot, or phoma spot is serious use Bordeaux (3–4–50) instead of lime-sulphur.
(7) Sixth summer spray. Apply about 12 to 14 days after No. 6. Make later sprays at intervals of 10 days to 2 weeks, where apple blotch, bitter rot, or phoma spot is serious.	Codling moth, lesser apple worm, apple blotch, bitter rot, sooty blotch, curculio, phoma spot.	Same materials in the same proportions as for the fifth summer spray.

equipment and knowledge which would justify departure in this respect are rare indeed. The timing is based on phases in the life history of the pests or their hosts which render control feasible at one time and not at another. Scab spores may lie inactive one day and, with a rain intervening, infection may be well advanced two days later (Fig. 129). Sometimes when spraying has been discontinued because of rain and resumed perhaps 24 or

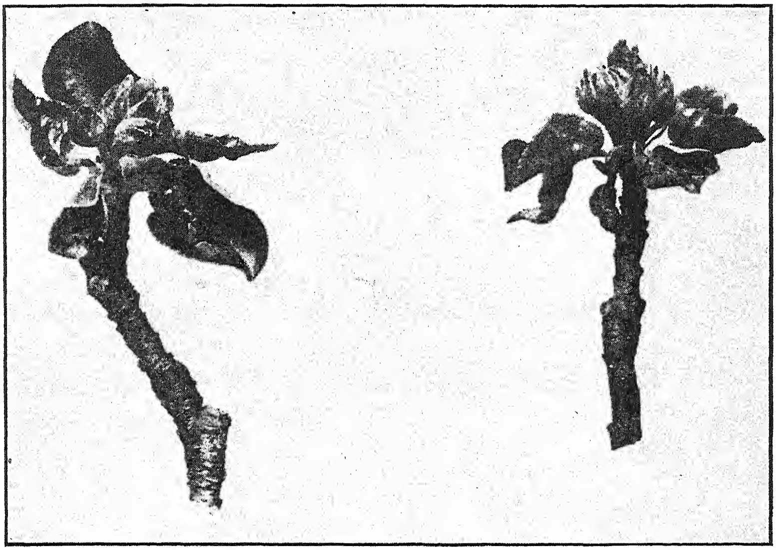


FIG. 129.—The "pre-pink" stage of the apple blossom cluster. For scab control 3 days' delay at this time in applying a fungicide might just as well be 3 months or a year's delay.

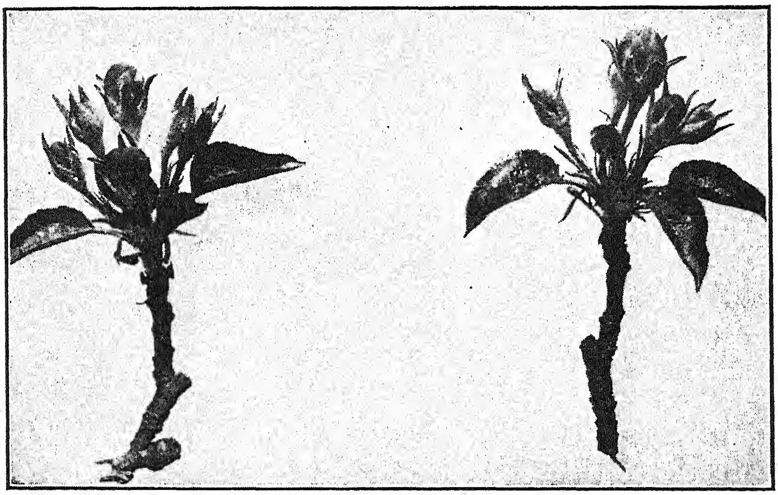


FIG. 130—The "cluster-bud" or "pink" stage of the apple-blossom cluster, another critical stage in timing spray applications.

48 hours later, the break is indicated by the distinctly heavier infection in the trees which were unsprayed during the rainy period. Application of the so-called "calyx spray" can be completely successful only within a few days. At no point in the business of fruit growing is the old adage that "a stitch in time saves nine" more applicable.

SPRAYING EQUIPMENT

Not only must spraying begin on time; it must end on time. Codling moth larvae are not frightened by the sound of the sprayer on the distant side of the orchard, and they keep on working until they are poisoned. Equipment must be more than adequate to cover the orchard in the allotted time, since allowance must be made for interruptions from unfavorable weather, breakdowns, and the like. Experience shows that the elapsed time from the beginning to the end of an application may be double the time spent in actual spraying, and effectiveness may decline rapidly toward the end. The last tree sprayed is likely to be as important as the first. Lack of adequate equipment places the orchardist in a dilemma; if he sprays thoroughly, some of the trees will not be protected in the proper time and if he tries to cover the whole orchard in time all the trees are imperfectly protected. A small outlay in spare parts may deprive the fruit grower of an occasional excuse for going fishing, but it keeps the sprayer moving.

Successful control of orchard pests hinges not only on spraying with the right materials at the right times; it depends to an equal extent on the thoroughness of application. Evidence on this point is furnished by the fact that fruit from the tops of tall trees where good spraying is difficult seldom grades out as well as that harvested from the lower limbs of the same trees, though conditions for scab development are less favorable there. Not infrequently three-fourths of the blemished apples are harvested in the top fourth of the tree. Foliage, fruit, and bark are fully protected only when their entire surface is covered with a film of the spray material. This necessitates the use of more material per tree than is common in many orchards; trees which require 10 to 15 gallons of material for thorough coverage often receive only a third or a half of that amount.

SPRAYING NON-BEARING TREES

Many who follow the spray schedules closely when the crop is good neglect to spray when the crop has failed. This course should be followed only after careful consideration. For some fruits, the sour cherry and the gooseberry, for instance, the spray schedule is designed primarily to combat foliage pests, those attacking the fruit itself being of secondary importance and held in check by the measures which control the foliage parasites. In these cases, there is as much reason for following the complete spraying schedule in an "off" year as in the bearing year. Failure to do this, though not reflected directly or immediately in crop yield or grade, may prove disastrous to the future health and productivity of the trees. For some fruit crops, however, as the apple and grape in many sections, the spray schedule can be materially curtailed during an off season without injury to the tree, for it is designed chiefly to control pests attacking the fruit. Similar considerations should govern the spraying of young trees prior to their bearing. If these trees require foliage protection at all, their vigorous growth should receive cognizance. Through a large part of the growing season formation of new leaves is almost continuous on rapidly growing shoots, and in a few days after a spraying, though the material was applied perfectly and adhered perfectly, the tree may bear a considerable amount of unprotected foliage.

SPRAYING IS INSURANCE

The practice of spraying has often been likened to the taking out of an insurance policy against losses due to insects and diseases, and its cost to the insurance premium. Accident and sickness are sure to come; so are losses from insects and diseases. The nature of the spraying schedule, like the nature of the insurance policy, should depend primarily on the risk, and secondarily on the cost involved. If complete protection is to be guaranteed, a full schedule must be provided; but in many, if not most, cases, protection beyond a certain point or degree is hardly necessary. The individual is warranted in taking certain chances, and the fact that he takes them does not stamp him as foolhardy. Whether he is wise or foolhardy depends on what chances he takes, on how well acquainted he is with his own conditions, on the nicety of his judgment. For the fruit grower this involves a

knowledge of environmental conditions, of varieties, pests and market conditions. The wise individual will take out his insurance in a sound company. Similarly the wise grower depends on well-tried standard spray materials, manufactured and sold by reliable firms and leaves experimenting to others. Taking a chance on omitting some important spray from the schedule is comparable to permitting the insurance policy to lapse temporarily. Sometimes it works out all right, but often it does not.

The simile that likens spraying to insurance, though generally accepted, is, however, really only superficially applicable and obscures some rather important differences between the two. Insurance provides reimbursement for losses; spraying prevents them, but it provides no refund in case of failure. Insurance costs are graduated according to the probabilities of occurrence of the various contingencies against which provision is made, while spraying expense depends on the cost of the materials required and the number of applications necessary and it has little relation to degree of necessity; indeed, one of the most expensive items in the schedule is protection against aphids, whose occurrence is extremely uncertain.

If spraying requires any analogy, the process of immunization, though not perfectly comparable, approaches rather closely in some respects to filling the requirements. Immunization prevents the contraction of certain diseases or reduces the severity of their attacks; ordinarily it is applied, however, only as probability of its need develops. In well-regulated communities, inoculation against typhoid fever is not necessary, but in civil emergency and in military life the menace from this disease is great enough to justify universal inoculation. Under no circumstances, however, is treatment for purely tropical diseases necessary in north temperate regions. Similarly, in the apple orchards of Illinois, warfare on San José scale must be unremitting; in Michigan it can be treated wholly as an emergency measure and in most Vermont orchards it is never necessary.

Fitting a spray schedule to a particular orchard requires cognizance of more factors than determination of the need of immunization. The latter is decided on the basis of probability of infection, while departure from the full spraying schedule necessitates consideration of four variable quantities: the probability of the pest's occurrence, the damage it can do, the cost of prevention and the value of the crop. Sometimes the saving

warrants the risk, but the risk must generally be small to justify any curtailment of the schedule, however large the possible saving.

Improvement in the mechanical aspects of spraying is often more economical and always safer than curtailment of the schedule. Judicious location of water-supply facilities with a view to saving long hauls before and after each spraying, and arrangements at the sources to ensure rapid delivery of water to the sprayer will effect material economies. In many orchards much more time is spent in filling the tank than is devoted to actual spraying. Sometimes an additional well saves the cost of one spraying a year through reducing the cost of all. Engine and pump should not only work well, but they should be of types suitable to the work. Seemingly trivial matters may be very important. Selection of the disk proper to the operation at hand or replacement of a worn disk at the cost of a few cents, besides saving material and time, is likely to ensure better coverage. Economies of this sort are effective with every application made, and most fruit growers can cut spraying costs more effectively and more safely by looking carefully into these items than by curtailing schedules. The few best fruit growers do both.

One parallel between immunization and spraying is generally overlooked. Vaccination has made smallpox, once very common, so rare that the new generation hardly knows or fears it and does not fully appreciate the virtue of the treatment which has produced freedom from this scourge. Its very efficacy has dulled appreciation of its worth. Similarly, rigorous combating of some pests has so nearly eradicated them from single orchards that careless treatment may for a time go unpunished. This leads to further laxity, increasing until a severe penalty is exacted. Even the most conscientious fruit growers generally have to pay at some time for tuition of this kind and some men take expensive post-graduate instruction in this subject.

CHAPTER XIX

FINISHING TOUCHES

Nautical lore contains numerous instances of ships returning from long voyages only to be wrecked at the entrance to the home port. Likewise, many a promising fruit crop has been carried safely through most of the season only to have its success marred near the end by circumstances more fully within the grower's control than the difficulties already surmounted. Success in producing crops and in protecting them from insects and fungi is more common than success in handling them so as to realize the utmost on their salability. More fruit is lost at the grading table and more profit is lost through lack of grading than is taken by insects and disease; beyond this stage of handling are other possibilities of loss that only too frequently become actualities.

Fruit growers as a class are comparable to manufacturers who have mastered the factory process to the extent of producing a useful article, but have failed to provide adequately for making it attractive and for distributing it properly. When he buys a keg of nails, the fruit grower specifies the size he wants and resents receiving a mixture, but he has not extended the same service to his own customers, failing perhaps to realize that fruits of various sizes have various trade uses, almost as definitely as nails. He expects, when he buys a sprayer, that it will be painted, partly for the sake of appearance and partly because it will last longer, yet he has frequently been remiss in providing for appearance and keeping quality in the product he markets. Much of the success exemplified by the rise in the consumption of oranges from 4,000,000 boxes in 1889 to 35,000,000 boxes in 1923 is due to the interest taken by the growers' organizations in the fruit after it leaves their hands and to their efforts toward making almost impossible the purchase of poor oranges.

Those familiar with the operation of manufacturing organizations know how frequently the sales department finds occasion to complain of the need of better support from the production department; without a satisfactory product to market, the best

sales organization is helpless. Similarly, improvement in the marketing of fruit must, in many cases, begin in the orchard. Nowhere has the relation between production and sales been more brilliantly exemplified than in the apple industry of the Pacific Northwest. Only a newly settled region could have courage to plant millions of apple trees 2,000 to 3,000 miles from a market for their product at a time when those markets seemed already well supplied from nearby sections and when heavy crops in those sections had already brought the threat of overproduction and the actuality of extremely low prices. Using the varieties grown in eastern orchards it had no novelty or superiority to offer in this respect. The success of the effort is attested by the average of 38,923 carloads shipped annually from 1920 to 1924 and by the presence of western apples in practically every fruit store, grocery and restaurant of any consequence. It is one of the great achievements of American commercial horticulture.

No lustre is taken from the splendor of this achievement when it is stated that much of this success has been due to a favorable combination of circumstances. Of course, credit must be given the sunshine and the soil, but these are really the least important items. The lack of previous orchard experience that characterized a large proportion of the earlier fruit growers of this section was in reality a great asset, for they were open to new ideas and had no bad horticultural habits to overcome. More important still, the greatest and unchanging horticultural disadvantage of the Northwest—distance from market—has been a great factor in its initial horticultural development, for it has defeated every attempt to market anything but the best fruit. While many eastern apple growers were still trying to force the housewife to sort apples out of a second-hand flour barrel, the green and the wormy apples for pie and sauce, the small apples for the children, and the large fair apples "for company," their distant competitors were doing a far more rigorous sorting at the orchard, for poor apples would not pay the freight charges on a 2,000-mile haul. The adoption of the box package necessitated absolute uniformity in the size of the contents, which has appealed more to eastern trade than the package itself.

Not all of the principles founded on western experience are applicable in other regions or with other fruits. There is profit in medium-grade apples if they can be put on the right market

cheaply enough, but transportation charges are equal for good and for poor fruit in similar packages and the market returns are generally higher for the good fruit; production of the best grade is, other things equal, more likely to be profitable. However, the orchardist cannot sort out 25 per cent of his crop for the fancy grade without diminishing the value of the remaining 75 per cent; if he is to make a profit from high-grade fruit the percentage of poor grade stuff must be small. As orchards grow older this condition becomes increasingly difficult to maintain.

The production of fancy fruit necessitates close attention to all the ordinary phases of orchard management from pruning to spraying, but these must be supplemented by some finishing touches. Many of these are connected with the picking of the fruit, its grading, its packing, and its storage. Some, however, are applied before picking begins. Thinning of fruit, for example, has long been a routine matter in peach growing, but the practice of thinning a commercial apple or pear crop, though not original with the Northwest, received its first general application there. Its advantages are numerous. Imperfect fruits, for instance: those showing stings, frost rings, or limb bruises, are removed. Total yield may or may not be reduced but the fruits that are left attain greater and more uniform size. Harvesting costs are reduced almost enough to compensate for the cost of thinning—if the original set of fruit is heavy. Indeed, thinning has been found so profitable, particularly in years of heavy production, that the practice has been extended to most of the tree fruits where quality brings a premium.

Among the finishing touches many practices have been recognized and applied generally by fruit growers. Only a novice would pick most fruits without stems, especially perishable fruit such as cherries for the general market. Careless indeed is the grower who allows his pickers to tear off fruit spurs in picking apples, thereby destroying the fruiting machinery of the tree and virtually ensuring punctures in the skin of fruits adjacent in the package. Actual count, however, has shown nearly 25 per cent of some lots of Northern Spy apples delivered at the packing shed to be so bruised as to necessitate culling; much of this bruising was due to careless driving over a culvert almost within sight of the packing shed. As these apples hung on the tree they were perfect—and bringing them to this stage had cost something in labor and expense—and as they were delivered for packing they

were as worthless as wormy apples. The grower would have been ahead financially had he left a quarter of his orchard untilled and unsprayed and done his harvesting and hauling carefully. Northern Spy is particularly susceptible to handling bruises; this is one of the small details that can assume considerable importance.

CONSUMERS' FANCIES

The fruit grower, more or less a connoisseur of fruits, long assumed that the consumer's knowledge of varieties equalled his own and that excellence of quality would be appreciated in the city, even when hidden under a rather unattractive appearance. This was in a measure true when cities were small and their populations composed chiefly of "farm-raised" people, but time has developed generations of city-bred people who have no first-hand knowledge acquired in a family orchard and no childhood associations to make some old plain-appearing favorite, such as Roxbury Russet, appeal on sight. Not having the connoisseur's knowledge, these people have developed their own standards of excellence; in these, appearance is paramount. There is nothing unnatural in this emphasis, for the fruit grower himself does the same thing in selecting products with which he is unfamiliar; the northern apple grower buying a watermelon for his Fourth of July dinner selects a Tom Watson and ignores the Irish Gray, while the southern watermelon grower is likely to select a Ben Davis apple in preference to a Grimes Golden.

Instances of preference founded on appearance, and particularly on color, are numerous. Yellow-fleshed red-cheeked peaches, purple-skinned or blue plums, blue grapes, and red apples have far greater chances of attracting general favor than the corresponding fruits with other colors. Pink-fleshed grapefruit has not been successful and it is doubtful whether the best of quality could sell a yellow raspberry, a white blackberry, a pink strawberry, or a blood orange. Large red strawberries usually bring better returns than smaller berries of better flavor and texture but poorer color. The "finish" acquired by apples and pears in the intense sunshine of irrigated sections establishes a predisposition in their favor. Color preferences are not immutable, as the rise of yellow sweet corn and the withdrawal of favor from white peaches attest and in some markets yellow apples sell

well, but horticultural history shows that meeting the demand is generally more profitable than trying to change it.

FRUIT COLORATION

All this lends interest to the chemical and physiological processes connected with pigment formation and those orchard practices that promote it. Color is, of course, primarily determined by the nature of the varieties selected for planting, but much of its intensity depends on growing conditions and subsequent treatment. Some fruits develop their pigments irrespective of direct exposure to sunlight. This is true of cherries, grapes, and berries of all kinds, in which the full color depends principally on a large leaf area. With these fruits, cultural practices that promote vegetative vigor and protect and preserve the foliage are best suited to develop high color. On the other hand, some fruits develop their pigments only when the fruit is exposed directly to sunlight. If a brilliant color is to be obtained with apples and peaches a particularly luxuriant development of foliage must be prevented. This necessitates greater care in irrigation, fertilizing, and soil management in general, and sometimes the exercise of some niceties in the art of pruning that are not imperative with other fruits. A few apple and peach growers occasionally resort to summer pruning to admit light to their ripening fruit, but this practice is by no means general or even common. On the other hand, full exposure to sunlight through complete defoliation, as sometimes follows spray burn—or occurs in cherries as a consequence of leaf spot—may prevent the attainment of proper color as well as size. Even in apples, color does not depend entirely on exposure to sunlight. Temperature often influences coloring; light frosts at the right season seem to accomplish what sunlight has failed to do. Some varieties of apples develop a slight color when picked green and kept in storage. Under these circumstances York apples acquire a delicate pink tint that was at one time in great demand on the English market and in growing Yorks for export full coloring on the tree was carefully avoided. Frosts and other temperature phenomena are not under the fruit grower's control but he can do much toward securing the desirable temperature effects on color and finish by choosing varieties that are suited to local temperature conditions. He can, in some cases, adopt cultural practices which intensify color. Some outstanding enterprises, such as the Marshall

orchard in Massachusetts and the Hitchings orchard in New York have owed much of their success to the brilliant appearance of the fruit produced under the sod-mulch system used in those orchards. Sometimes a grower can so arrange his planting as to place on the lighter soil those varieties that should be red and on the heavier soils those that should not.

FINISH

Finish, however, is not a matter of color alone. The term implies a gloss and texture of skin that appeal to the eye. It is more a varietal characteristic and a product of climate than of culture. This does not mean, however, that the grower should fail to take it into account. Fortunately, the environmental conditions that are conducive to the development of the best finish and storage and market quality in one fruit or in one variety are often different from those that are best for another, and the wise grower selects his kinds and varieties so as to capitalize the advantages of his environment rather than continually to suffer the penalties for its disadvantages. Apples from a foggy region lack luster, but strawberries or plums or grapes do not. It is in some measure for this reason that Louisiana is famous for strawberries, the Santa Clara valley for plums, Wenatchee for apples, and not otherwise. The better apple growers of the Pajaro Valley cling to Yellow Newton and Yellow Bellflower with which a perfect finish is clear yellow and waxy, and they do not essay the culture of Winesap and Delicious, which require intense sunshine and frosty nights near the harvesting season to attain the brilliant red and glossy standard. The pear growers of the Willamette Valley, which is cool and humid, sell their fruit to canneries which do not discriminate against a dull, half-russet fruit if it has suitable size and quality of flesh. They would be at a disadvantage in competition with the growers of the Rogue River or Sacramento valleys that produce a glossier product for the fruit-stand trade of the eastern states, but these differences disappear when the fruit is canned. In some cases the choice of spraying materials affects the finish of the fruit.

QUALITY

With all due weight accorded to appearance the equal importance of quality must be conceded. The consumer may select

certain apples because of their appearance, but he would not buy apples at all if he had no recollection of enjoyment from some earlier purchases. Most men buy but one wedding ring in a lifetime, and one coffin suffices for each person, but the consumer is urged to eat "an apple a day." He uses about so much salt and so much wheat and will not use more, but his consumption of apples is governed chiefly by the satisfaction he secures in eating them. According to the estimates of dietitians, an adequate fruit diet for the American people in 1922 would be about 340,740,000 bushels. Actual production in 1922 was estimated at 332,318,400 bushels, or 97½ per cent of the adequate diet. This means that any further expansion of the fruit industry as a whole or of the culture of any particular fruit depends somewhat on the extent to which the consumer is, even in spite of himself, if necessary, protected against buying fruit of poor quality, however attractive its appearance may be. Apples like Ben Davis and Ingram and plums like the Lombard have been a great boon to the rising banana and orange industries.

To no small degree, this matter is adjusting itself through the gradual specialization of various regions on varieties which attain high quality within their borders. No recognized apple section, for example, is uniformly superior or inferior in all varieties; the Winesap of Virginia or Wenatchee excels the Winesap of New York and New England as the Northern Spy and McIntosh of these sections excel the same varieties grown south and west. Gravenstein, King, and Rhode Island Greening attain excellence in the Northeast that is rarely approached west and south, but the Jonathan, Grimes, and Newton Pippin of this region are distinctly inferior. Much of the varietal difference in excellence is due to the prevalent temperatures of the growing and ripening season, though the character of the soil has some influence; Northern Spy is generally at its best on rather heavy soils and McIntosh on lighter. Even in the best location for the varieties he grows, the orchardist can—and frequently does—throw this advantage utterly away.

WHEN TO HARVEST

It has been said that a good time to sell is when someone wants to buy. Not infrequently growers extend this idea to the point where they seem to think that a good time to harvest is when

someone wants to consume. This leads them to place on the market full-sized but really immature fruits of many kinds, fruits that often lack very much in quality, if not in color. Products of this kind may bring good prices because they are earliest on the market but they are not the kind that sustain demand and they often kill the demand for late maturing, better varieties of the same kind. Ton for ton, Champion grapes have probably netted the Michigan grape grower greater profit than the Concord but their poor quality makes every ton sold spoil the market for several tons of Concord. Duchess apples that are sold green on Aug. 1 may bring double the price of better lots of the same variety sold 10 days later but these are the fruits that make old men say that apples are not what they used to be. Blackberries are truly green when they are red and they are not yet ripe when they first turn black; most blue grapes are blue for some time before they attain the full measure of their excellence. Loganberries do not attain sufficient quality to warrant shipment until they are too soft to ship and for this reason they have never been successful in the eastern fresh-fruit trade. On the other hand, in American markets custom demands green and wholly unripe gooseberries; this habit may account for the smaller favor accorded the gooseberry in the United States than it receives in England, where it is not picked so green.

Any grower knows that to attain high quality most fruit should remain on the tree until it has attained full size and proper color. He also knows, however, that fruit—except prunes, apricots, and peaches for evaporation—must be picked before it drops from the tree; this consideration often necessitates starting picking rather early, for there may be much to harvest with a limited amount of labor. If picked too early, fruit never develops proper texture and flavor and may scald or wilt in storage. This may happen even though the fruit is fully covered by the overcolor. If picked too late, it softens quickly and soon breaks down and becomes mealy. Only a small percentage can be harvested when conditions are ideal; much of it must be picked a little too early or a little too late. The real problem is to reach the best compromise and to know which varieties are most tolerant of premature or of delayed picking. Generally the wiser course is to leave most fruits on the tree as long as possible if facilities for proper care after picking are not available. Since the processes of ripening and decay proceed much more rapidly once

the fruit is taken from the tree, picking should not proceed faster than the fruit can be properly stored or packed.

In 1604, an unknown author wrote, in a work on marketing of fruit:

You must note that there be pippins and other winter fruits, although of one sorte, and grown in one ground or orchard, that will last better then other some; and of some trees growe better fruite then of other some of the same sort, & in the very same orchard. For, where the sunne hath most power or shineth hottest, the fruite is harder grained, bigger, and of a better colour, then they that grow upon the very same tree, upon the lower boughes (which are called water boughes) or the inner boughes of the tree. For, the raine or moysture that lights upon the tree, falles to the lower parts; by reason whereof they never have any good colour, but are alwaies greene and soft, and eate very waterish; which causeth them, they can never last long, nor eat kindely.

These observations still hold good, and though sorting of the crop of each tree is generally impracticable, soil variations in many orchards induce differences in fruit ripening great enough to establish a desirable sequence in picking. One large Baldwin orchard in western New York is kept half in sod and half in cultivation, solely to extend the picking season. Fruit on the trees in sod is ready for harvest first, and while it is being picked that on the cultivated trees is approaching picking maturity.

To some extent the best time for picking depends primarily on the probable disposal of the fruit. For local consumption it should ripen on the tree until softening begins. This insures the maximum size, best dessert quality and the most attractive appearance. Apples destined for distant markets or storage must be picked earlier and the greater the distance or the longer the storage is to be, the earlier after the ground color begins to turn yellow must they be picked. In this stage the fruit is said to be "hard ripe." Much depends also on the kind of fruit and even on the particular variety. Making more than one picking is often advisable with the stone fruits. Summer apples, which are generally picked for immediate consumption, soften so rapidly, even when picked green, that picking before they are fully ripe is often advantageous or even necessary. The majority of fall and winter apples should be left on the trees as long as is practicable. Jonathans, however, must be picked rather early, because if they have been left too long on the tree they develop

in storage a spotting so characteristic that it is called "Jonathan spot."

Most pears, on the other hand, should never be allowed to ripen on the tree. Their fine eating quality develops only when they are picked green and are ripened away from direct sunlight, although if they are picked too early they shrivel and wilt before ripening. All over the surface of a young pear fruit are minute pores called lenticels, which are visible as small light-colored spots. These eventually become brown; when this occurs the openings have been covered by the development of a layer of cork and there is little danger of the fruit shriveling after removal from the tree and it may be picked as soon as it has reached the proper size. In most cases, however, the closing of the lenticels occurs so early that much higher dessert quality develops if this natural "seal-pac" product is left on the tree two weeks longer. For distant shipments, immediate picking may be necessary. Some varieties if left too long on the tree become gritty, because of the development of stone cells, and breakdown may set in at the core though the outside is still sound.

Though pears and apples develop flavor and strawberries develop color after they are picked, peaches merely become soft. The longer they stay on the tree the better is their flavor. In this case the common preference for home-grown fruit is justified; other things equal, California peaches are the best peaches in California, Georgia peaches the best in Georgia, and New Hampshire peaches the best in New Hampshire, since the early picking necessary for shipment to a distant point curtails the development of flavor. A comparable condition seems to prevail in most varieties of the red raspberry and in the cherry.

STORAGE

The responsibility of the grower is not ended with the picking. As soon as fruit is picked, it commences to ripen, and the riper it becomes the more quickly it breaks down and decays. This happens with perfect fruit, for much of this decay is independent of fungi and bacteria. It is physiological; according to some authorities it is a self-poisoning of the tissues. The process of ripening cannot be stopped, though it can be greatly retarded by keeping the fruit cool. Moreover, at day temperatures the processes of decay proceed twice as rapidly after fruit is picked than while it is still attached to the tree. It should never be piled

under the trees or left out in the sun, a practice once much in vogue to develop color. Sometimes it is packed immediately after picking and then placed in cool storage, but in case of delay it should be stored temporarily in a cellar or in some other form of cool storage. If large quantities of fruit at a high temperature are piled in a cool room they retain their heat for a long time; therefore anything that can be done toward cooling fruit before it is placed in storage is decidely beneficial. Fruit picked during the day may be left out over the next night to cool and then transferred to the storage early in the morning.

Cool or common "air-cooled" storage works on a very simple principle. During the fall picking season, the nights are generally cool and the days warm. At night all the doors and windows of the storage shed are opened to admit the cool air; during the day they are closed to exclude the warm air.

If no storage is available, an open shelter may be utilized. After it is packed, the fruit should be placed promptly in cold storage or loaded in the cars. Delay during any of this work is costly. All the previous labor and expense of pruning, spraying, fertilizing, and general culture may be lost at the last minute by neglect in the handling of the picked fruit.

In storage, most deciduous fruits should be kept at temperatures as near 32° F. as possible and high humidity should be maintained to prevent shriveling. Piling the crates in a manner which permits air circulation is likely to decrease damage from scald, and a type of container which permits some aeration has the same tendency. Wrappers retard the spread of rots from one fruit to another, and oiled wrappers are particularly effective in reducing scald.

With fruits, as with other products, the real finishing touches are put on when they are graded and packed for the market. The slogan adopted by some of the package manufacturing companies to the effect that "the package sells the fruit" tells part of the story, but only a part. More and more the demand in food products of all kinds is for smaller units of rigidly graded, highly standardized goods, conveniently and attractively packed. When sugar and salt, flour and coffee, crackers and raisins were sold by the grocer from bulk stock, when butter was sold from crocks and lard from tubs, apples could be marketed advantageously in barrels or even in "bulk." Sugar and flour are now sold in sacks; coffee and raisins—even eggs—are offered in paper

cartons, attractively labeled. Perhaps apples, peaches, and plums are not suited to sale in packages of these same kinds but in most trade channels the basket, the crate, and the box are surely replacing larger containers and with the changes in style of package arises a demand for standards as rigid as those set for breakfast foods or cookies. In a sense, pack and package testify to the grade and quality of the fruit itself, for an attractive pack requires the selection of uniform fruit. Grading and packing are important items in establishing a reputation and a good reputation is the most cherished asset not only of the individual grower but of the entire section or district to which he belongs.

When—and not until—goods are thoroughly standardized they can be advertised locally and nationally, and they can be merchandised rather than merely sold. Standardization enables the housewife or hotel chef to order oranges or raisins or grapefruit or bananas over the telephone, knowing how the order will be filled and what will be delivered almost as surely as with bread or flour or breakfast foods. When apples or pears or peaches or grapes or blueberries can be ordered with the same confidence, the industries supplying these commodities will begin to enjoy some of the phenomenal growth that has characterized some other food industries.

CHAPTER XX

TRENDS IN FRUIT MARKETING

No event recorded in the history of the western world during the past six centuries has been more important, perhaps, than the gradual changes arising from the development of commerce and invention and remodeling the manner in which men lived. The luxuries of one generation have become the necessities of another. Old inventories and wills show that in the Middle Ages the owner of the manor house had far less household furnishings than the tenant of the present. Still more important sociologically are the changes in diet. In medieval times both peasant and noble in England and throughout northern Europe lived almost wholly on salted meats and grains; summer brought but little addition to this restricted, though sometimes abundant, food supply. Because of this limited diet, scurvy was rampant, and perhaps really of greater national importance than the more dramatic plagues which occasionally ravaged Europe.

As time went on the expansion of commerce increased purchasing power and agriculture became more diversified; these influences combined to provide greater variety in diet and scurvy gradually became known chiefly as a disease of army camps, besieged cities, and ships long at sea. In increasing its vegetable and fruit diet, the race had unconsciously freed itself from one of its most common diseases. Physicians had, at first, little influence in the matter; in fact, the herbals, which were virtually the materia medica textbooks of the sixteenth and seventeenth centuries, rather discouraged extensive consumption of fruits, particularly when uncooked. By 1795, however, knowledge of anti-scorbutics had progressed so far that lime juice was added to the ration prescribed by the regulations of the British navy.

Withal, the tremendous and accelerating increase in the use of fruits and vegetables characteristic of the last few centuries has been due to factors quite separate from their anti-scorbutic properties. People have eaten these products chiefly because they liked them and because they could get them. Perhaps

taste itself has not changed materially, though it can be educated, but there is good evidence that the number of really palatable fruit varieties has increased materially in a comparatively short time; this alone would increase the demand. Far more important, however, have been influences whose origin was not horticultural. Chief of these has been transportation, which has enabled people to obtain a wide variety of products in large quantities.

TRANSPORTATION

The first pineapple brought into England was presented to Oliver Cromwell. Not much over a century later pineapple production under glass was well established in England. Attempts to build the industry in the infant United States failed because the sailing ships of the time could deliver outdoor-grown pineapples from the West Indies in good condition in Philadelphia, New York, and Boston far more cheaply than they could be produced in the greenhouse. The longer time required for the voyage to Europe made commercially possible the greenhouse production of pineapples in England until the advent of the steamship, cutting down the time required for crossing the ocean, brought West India pineapples to Europe in such quantities that the greenhouse industry disappeared. A rare luxury had become a common article of diet.

The larger cities of the eastern United States for a time supported a greenhouse grape industry which has since disappeared, partly because of increased production of outdoor grapes near at hand, made possible by the development of new varieties, but also because of importation of "out-of-season" grapes from great distances, consequent upon the development of more rapid transportation. Another product had become accessible to a greater number of people.

Transportation did not confine itself, however, to providing competition for fruits grown under glass. Men who emigrated from New England at the close of the eighteenth century and settled as pioneers in western New York lived to see the Erie canal and the railroad used to transport apples destined for sale in Boston competing with the products of local orchards. This was the first new and "distant" fruit region which developed directly as a result of improved transportation facilities. Later this section was to be in turn provided with the

keenest kind of competition—from California in pears and from Washington in apples—by the railroad. In recent years the apple industry, in general, has become keenly aware of the competition involved in the marketing annually of 25,000,000 boxes of oranges brought by rail from California and Florida and of 29,000,000 bunches of bananas brought by a fleet of steamships from Central America and the West Indies.

For a time the producer of the more perishable fruits encountered little competition from outside his own locality. Had Henderson Lewelling, in 1847, established a peach orchard in Michigan instead of taking his wagon-load of nursery stock from Iowa to Oregon he would probably have been richer, if less famous, for the few fruit growers along the lake shore, shipping their product by boat, had a monopoly of the Chicago market and their returns exceeded those of the majority of the "forty-niners." Everywhere the early variety of each fruit was eagerly sought and the first fruit on the market, regardless of its quality, was likely to be very remunerative. The refrigerator car has materially altered this situation. The fruit whose only merit is earliness is likely to meet stiff competition in its territory from a better later variety shipped in from the south where it ripens early. Some strawberry-producing centers, for example, have been most successful with midseason or late varieties, which ripen after their more southerly competitors have ceased to be factors in the market. The recent plantings of the Concord grape in Missouri and Arkansas, filling the Chicago market ahead of Michigan Concords, promise to eclipse the Michigan Champions which have sold only because they precede Concord in ripening. For the consumer, the market season for each of the perishable fruits has been materially lengthened. Florida strawberries are on the market at New Year's and this state is through shipping before the maple sap starts to flow in Maine and Michigan, where the strawberry season ends in July. Here, then, is a crop which at any one point has a season of 1 month, appearing on the market over half the year.

REFRIGERATION

The refrigerator car has also provided competition between sections whose crops ripen simultaneously. Fresh prunes from Idaho compete with Michigan and New York plums; Michigan

raspberries must share the Chicago market with red raspberries shipped from western Washington. Furthermore, it pits one crop against another; watermelons, canteloupes, peaches, and plums, gathered from all over the country, contend simultaneously for the huckster's attention and have succeeded rather well in diverting him from the early apple.

As a partial compensation for crowding the crop from many regions on the market at once, refrigeration has lengthened the season. A surplus of peaches or pears in western New York sends a part of the crop into storage, relieving the immediate surplus and permitting more profitable marketing of the whole crop. Its influence on apple marketing has been even wider. Apples are on the market throughout the year; in an ordinary season early apples from California, Delaware and southern Illinois are on the market before the last of the previous season's crop from New York and Washington are sold and for the retail grocer merchandising them has come to be nearly as much a part of the daily routine as selling sugar or soap.

The early development of extensive commercial apple growing was confined chiefly to the northern states; Maine, New York, and Michigan were dominant in the market because of the superior keeping qualities of their apples. In the southern states insects and fungi made the crop more difficult to produce and the apples then grown there, the staple varieties of the North, apparently lacked keeping quality under southern conditions. Spraying has enabled southern growers to produce abundant and clean crops; better selection of varieties and cold storage promptly after picking have enabled states such as Virginia and West Virginia to supply winter markets very acceptably. Indeed, in the Winesap, which grows well in Virginia but poorly in the northern states, the South has a late keeping apple of a quality equal to that of anything its northern competitors can offer. As at least a partial offset to this influence, refrigeration has enabled the northern states to extend their winter apple season so that apples which were formerly considered good only until Christmas are now sold in late February. This has had the effect of crowding out those varieties, such as Ben Davis and Roxbury Russet, whose chief merit is their long keeping quality, as better apples are now available during the season in which these varieties were formerly alone on the market.

Refrigeration and transportation facilities have made possible more extensive shipments of apples to European markets. Though this trade was well established in the days of sailing vessels it was confined to winter apples produced along the north Atlantic seaboard; with the aid of fast steamers and refrigeration it has expanded considerably. Early apples, such as Wealthy, are shipped from New Jersey to England, and large quantities of winter apples are shipped from Seattle through the Panama canal, reaching their European destination in good condition despite a long voyage, part of which is through tropical waters. This export trade relieves the pressure on the home markets in years of heavy crops.

MANUFACTURED PRODUCTS

The rise of the canning industry, chiefly since 1885, has provided markets for remote sections where crop disposal would be difficult without some such outlet. Indeed, in some sections the canneries handle the greater part of certain crops. The large peach crop of California is sold chiefly in tin cans, and the pear crop of the Willamette valley in Oregon finds a similar outlet. In regions closer to the large markets the buyers for the canneries compete with those for the fresh trade, Michigan and New York, for example, supplying more than half the total pack of raspberries. From 1910 to 1920 the total pack of the nine principal fruits increased considerably over threefold.

The combined effect of better transportation and refrigeration facilities, not only increasing the amount of fruit on the market at any one time, but also lengthening the time during which it is on the market, has been to increase greatly the total consumption. Besides that portion of the strawberry crop marketed locally, the annual carlot movement has averaged in recent years over 15,000 cars. The markets of the country could not absorb anything like that amount in one month, but spreading the load over several months makes the strain comparatively light. No one section could find market for a 35,000-car peach crop, but spreading the distribution from May to October or even to November has disposed of crops considerably larger than this figure. A similar condition prevails with other perishable fruits. The same statements apply with equal or greater force to the canning industry, which has opened a new outlet for fruit of

nearly all kinds. Probably three-fourths of the entire commercial production of sour cherries is marketed in cans.

STABILIZING AND DISTURBING FACTORS IN DISTRIBUTION AND MARKETING

Good transportation has given the fruit crops a considerable amount of fluidity, so that they tend to flow into any vacant space. A shortage in the Michigan peach crop, for example, is usually filled in part on the Chicago market by increased shipments from Colorado or Utah or New York, with consequent readjustments elsewhere. To no small degree, the nation as a whole is the marketing unit, and prices at any one time tend toward uniformity throughout broad areas. Fruit growing in any one section is increasingly affected by fruit growing in other sections, remote perhaps by many miles, but placing their product on the market at the same time. The great range of territory from which crops are marketed makes universal shortage unlikely, and tends to stabilize supply and prices. This condition is tending gradually toward an eventual localizing of fruit production in regions best suited by climate for heavy and timely production, toward increasing the importance of natural advantages and diminishing the importance of distance from market.

A permanent geographic adjustment, however, is not likely. Present distribution of the industry is made, naturally, on the basis of the varieties now prevailing on the market. These may change, and with them conceivably the whole geography of an industry. The pear growing of the present is based chiefly on the production of the Bartlett pear; other varieties are largely incidental. Should plant breeders be successful in their efforts to produce a pear as popular on the market as Bartlett, with the added quality of blight immunity, wide areas of the southeastern states would be thrown open to commercial pear production and the whole geography of the industry might easily be made over. The present distribution of peach production—California excepted—is based on the dominance of the Elberta, a midseason variety. Georgia, at the southern edge of the peach area, can sell almost any variety that precedes Elberta, because it is offered when no Elbertas are available but it can sell no variety that ripens later, when states to the north are shipping this variety. Michigan and New York, at the northern edge, could sell any variety that ripens later—could they ripen it—because there

would be no Elbertas then available. If, however, an early variety were to supplant Elberta in popular favor, the Georgia period of market dominance would be shortened and the northern states would have a correspondingly longer period with greater total sales. On the other hand, were the supplanting variety distinctly late in ripening, Georgia could sell her whole range of varieties and the most northern states might be wholly crowded out. These cases are hypothetical but possible; comparable changes have occurred and will occur. Recent heavy crops from young McIntosh plantings in Massachusetts have resulted in a decrease in boxed apple sales in Boston. The industry will never become wholly stabilized.

MARKETING FUNDAMENTALLY A PRODUCTION PROBLEM

Careful consideration cannot fail to indicate that the horticultural problems involved in the marketing of fruit crops are far more numerous and more intricate than the economic problems. The fruit industry as a whole is far behind most other industries in its knowledge of consumer's demands, of just what will meet the requirements of various groups of consumers—and of presenting its products acceptably to these various groups. It suffers grievously from lack of unified direction in preparing its product for market and in distributing it, though time is gradually wearing away the ancient notion of the divine right of the individual to ruin a community's market reputation. Grading laws are a step in the right direction. Perhaps the ideal marketing machinery is yet to be achieved; certainly none in use at present runs long without creaking. With full recognition granted to these partly economic factors, the horticultural problems involved in marketing are far more important.

If a producing region has a product that the market wants, when the market wants it, almost any kind of marketing machinery will handle it. If the market does not want it, no kind of marketing machinery can handle it satisfactorily. Offering the market a product that it wants at the proper time is and must remain a problem requiring the best of horticultural knowledge, ability, initiative and leadership. Each section must look for market gaps and decide whether it can fill them. It must know what sections are its competitors in each commodity, what they can do, what they are doing and what they will be doing 5 or 10 years later. It must know its own capabilities and

the limits to them. It must know its competitors' difficulties and it must face its own. It must differentiate between surface ripples and deeper currents; it must know whether a high price for a certain variety one year is due merely to a temporary shortage elsewhere or is the result of a permanent decrease in production of that variety and it must govern its plantings accordingly. In short, it must plan its own development with constant reference to its place in the whole marketing system. Having done this, it has to face the problem of producing the commodities as cheaply as possible, for profit comes from cutting production costs as truly as from increasing sales prices—and of offering them to the trade in such condition and in such quantity that they can be handled with satisfaction to all concerned. Until human nature becomes standardized, this will remain the greatest difficulty.

In brief, most fruit regions fall far short of doing what they could to meet the horticultural aspects of their marketing problems. Some are not even aware of the existence of these horticultural shortcomings. Until all have done more than they have, horticultural leaders cannot rightfully delegate their responsibility to other agencies.

CHAPTER XXI

SUPPLYING LOCAL MARKETS

When transaction between producer and consumer is direct there is, on the whole, little occasion for formal grading of fruit. In the old days, now gone in most places, the farmer who supplied various families with a few barrels of apples year after year came to recognize that one family preferred to pay a moderate price, even if the apples were not all red cheeked and even though they were not all free of wormholes, while another family was willing to pay for apples that would be attractive on the table, and he governed his sales accordingly. In many cases the destination of each barrel was determined as it was packed. Transactions originating in an orchard 500 or 2,000 miles from markets, with the market itself unknown at the time the car is loaded, and several sales and resales intervening between the orchardist and the ultimate consumer, must be on another basis. Examination of every package in a carload is impracticable; even were an accurate enumeration of the red and the green, the wormy and the sound, apples stamped on the outside of each package, handling in carload lots would still be impracticable. More and more the market is insisting that the carload must be the unit. One wholesaler supplies the fruit-stand trade; for this, every apple must be practically perfect and the number of apples to the bushel must be known and be uniform; this trade needs carloads of apples of one variety, uniformly colored and with the same number of apples to the box. Chain restaurants want uniformity in their baking apples; their requirements run into carloads. The groceries supplying household trade have rather definite requirements, varying according to the nature of the trade they supply, but more or less uniform for each store or system of chain stores. Finally, the housewife, in many cases ordering by telephone, must have confidence that the apples will come up to specifications or she will order something else.

Almost all the wholesale apple trade is founded on ability to buy without inspection and sell without inspection, on assurance

that the goods are uniform and as represented. Nobody in the chain of handlers has time, facilities, or inclination to sort fruit; this must be done before it leaves the packing shed. When this is done and large enough lots of various grades and varieties are available, the several trade demands can be met.

Shipping to distant markets or through the chain of distributors that handle rail shipments, is becoming more and more a matter of standardization, to facilitate telegraph and telephone sales by the carload. Securing large lots of the various grades and sizes is much easier when the number of varieties is small; hence the pressure toward growing a very limited number of varieties in each shipping area. There is thus a twofold standardization —on varieties and on grades—becoming increasingly important and even essential for the orchardist who does not personally dispose of his crop.

ADJUSTING PRODUCTION TO LOCAL MARKET CONDITIONS

In sections distant from markets the individual orchardist must surrender most of his identity; he is virtually forced to grow certain varieties and in many cases to turn over his crop to be graded, packed, and marketed under a brand or a group name and he receives the proceeds according to the quantity and grade of his share. In the actual marketing he has little or no voice. He can increase or decrease his returns in accordance with the care he gives his orchard and his crop, but if he is dissatisfied with the disposal of the crop he can do little more than consign his fruit to a different broker or vote for a new board of directors in his cooperative organization. This situation is inevitable under the circumstances and has many advantages; excessive individuality with the closeness to market that permits it is the chief difficulty in some fruit regions. The majority of growers probably fare better under a system which takes the direct marketing rather largely off their hands, but there are those who do not find in it full scope for all their ability and do not reap the full reward that this kind of ability brings.

WHERE LOCAL MARKETING IS PRACTICABLE

By far the larger portion of the consuming population of the United States lives within territory where most of the deciduous fruits can be produced. This region is certain to remain the

most populous; as long as it has this population it is equally certain to continue producing fruit. Local conditions for growing the various fruits in this territory vary from good to bad and the product varies likewise, but until transportation costs and time can be annihilated, the local producer will be a factor. Some orchards located in sections where production is not easy are very profitable, for, as the difficulty of production increases, difficulty of selling decreases. That the local producer is a considerable factor is realized by those who travel the highways and see the processions of fruit-laden trucks bound to market. Statistics of this traffic are meager but some notion of its extent may be gleaned from the statement that in 1923 the Philadelphia market received from New Jersey 16,300 carlot equivalents of produce; of these 15,322 entered by auto truck.

Those who travel along the Boston Post road at the proper time do not need to inquire what becomes of the Connecticut peach crop, though official statistics, based on carlot shipments, sometimes ignore it. The Boston market alone receives each year from Massachusetts orchards more than twice as many carlot equivalents of apples as the state ships by rail to all points. Paralleling the steamship and railroad lines from South Haven and Benton Harbor to Chicago is the "M-11" highway, over which trucks carry a tremendous, though officially unrecorded, tonnage of peaches, grapes, and berries.

Just as the railroad and the refrigerator car have "made" the distant fruit regions, the auto truck and improved roads are remaking the regions closer to market. A truck is not run without expense, but in many of the large cities the cost of hauling fruit to the wholesale distributor's establishment from an orchard 50 or 75 miles out is very little more than the drayage charge to the same point from the railroad yards; consequently the producer can consider that the freight charge is virtually eliminated. Furthermore the saving in time is considerable; berries leaving Benton Harbor at night by truck are distributed on the market in Detroit and Chicago the next morning before the city draymen report for work. Two or three hours' difference at this time is likely to have a great effect on the returns for the shipment. Moreover, during the rush of the shipping season the grower need not pick fruit all day and run a truck all night; for in the same way that the tramp steamer which operates on no fixed schedule or route carries a large part of the sea-borne

traffic, fleets of roving trucks operate wherever business takes them. Working out of Indianapolis for example, they may first gather peaches from the south for the Indianapolis market; then as the ripening season moves north they may pick up loads in southern Illinois, and end their peach season hauling from Michigan. Most of these operators pay cash at the orchard.

In other cases the automobile permits the market to seek the grower. To what extent the roadside market stimulates total fruit consumption and to what extent it merely transfers the scene of the fruit sale, cannot be stated definitely, but it certainly

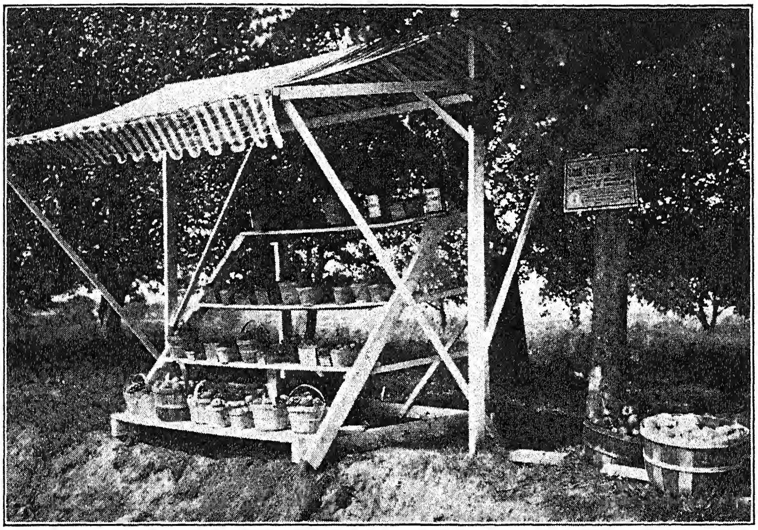


FIG. 131.—An attractive roadside stand.

increases sales from some orchards. There is apparently some exhilaration connected with a run into the country or a sight of an orchard that makes the city family cheerfully pay as much or more at the roadside stand for fruit it could buy in town, of as good or better quality. On a "good" Sunday one stand has been known to take in $20,000 for summer apples alone. Marketing costs are here reduced to a minimum. Owners of some productive apple orchards of between 20 and 30 acres have not bought a fruit package in five years; the consumer brings his containers with him. There are signs that this business will come to a period of readjustment and probably of regulation,

but in some form it will undoubtedly be a permanent marketing channel. It offers the greatest opportunity for individual initiative and an occasional possibility of the highest returns connected with fruit growing.

The tourist and resort trade, particularly in the northern states, has come in closer contact with the local fruit grower through the automobile. This trade creates, here and there, small markets—generally with limited supply—for summer fruits. It offers opportunities as yet not fully realized. Many of these summer resorts are close to orchards of winter apples whose owners are wondering about market possibilities hundreds of miles distant. Many summer hotels must have their supplies of berries shipped from distant cities because the local farmers are growing potatoes for the very distributing centers that supply these berries. Some fruit growers are alert to the possibilities offered by this trade and sell to the visitors not only sufficient to supply their own wants, but additional quantities to be sent to their friends at home; for example, a considerable trade in gift packages of sweet cherries has been developed in some of the Michigan resort regions. These packages are sent by parcel post as far as Florida.

THE PECULIARITIES OF LOCAL DEMANDS

Some of these outlets require diversification. Concentration on a few varieties, the best policy in a carlot shipping region, leaves the roadside stand or the individual supplying a group of retail stores but a short period of selling and consequently a diminished seasonal business. Not only is a succession of varieties necessary for the orchard whose chief outlet is of this nature, but diversification of crops is generally desirable. The grower who ships in carlots need not concern himself about a possible overproduction of good varieties in his own orchard, for when he has a larger crop than usual, he merely ships more cars; the exclusively roadside seller, on the other hand, must calculate his plantings carefully to have enough and not too much at any one time. This involves study of the passing traffic and real knowledge of fruit plants. He may find occasion to depart from the list of standard commercial varieties, which is based rather largely on shipping quality, though when he can plant varieties favorably known on the market he is keeping open other sales channels.

If he is near enough to town for the market to come to him, he is near enough to go to the market.

The fruit grower who hauls his crop to city markets likewise may find exceptions to the principles of sound merchandising as laid down for shipping areas and, perhaps unconsciously, rather widely applied to local marketing. Municipal market masters are often aware of neglected opportunities, a gap of perhaps 1 week or 10 days each season between the last of one crop and the first of another, when almost anything ripening at that period will sell. Planting should not, however, be based on one season's record, for a gap may be occasioned by a shortage in one year and the same period be abundantly filled the next year.

Various markets have their individual peculiarities; roadside stands at some points in southern Michigan sell Yellow Bellflowers to people in Indiana cars and Rambo to those in cars bearing Ohio license plates, while the Michigan trade wants Northern Spy. Racial composition in a city's population sometimes affects its market preferences; English people buy pears, gooseberries, and black currants more readily than most others. Various jobbers sell to trades with various demands; one may tend to specialize in cooking apples for restaurants, another in dual-purpose apples of fair grade for groceries, and a third may be particularly successful in disposing of cull apples. Retail stores vary in their demands in accordance with their respective clienteles. Grades and varieties should be offered to suit these preferences; this requires study of the trade. At least one fruit grower whose "McIntosh" trees proved to be Wolf River was able to find an outlet for his crop by personal visits to hotels and restaurants which needed good baking apples. Various trades prefer various sizes; large apples are not profitable when they are sold singly.

This multiplicity of outlets requiring different grades of fruits may occasion careful comparison of possible net returns. The carlot shipper's problem is simple so far as grades are concerned, but the local producer may find grading profitable with one variety, and he may actually net more with ungraded fruit in another. There are in every city many consumers who are seeking bargains and to whom "bargain" means low price. Apparently quality makes little difference to them, if only the price is satisfactory. In the same cities are consumers who demand quality first and to whom price is a secondary considera-

tion. To insist that the first group pay high prices for high-grade goods is as fatal to business success as to insist that the second group accept inferior goods at bargain prices. The second group will not buy a second time and the first group will not buy at all. The business of the orchardist who produces for the local market is to determine local market demands and then supply them to the best of his ability. He may find it desirable in some instances to supply the demand only of those who want the best, or that of those who want only the cheapest, or he may find it desirable to supply both, but in any case his function is to supply demand, to adjust his business to it, not to force it.

The statements just made should not be interpreted as meaning that those who grow for local markets can afford to ignore quality or grade. No consumer buys fruit primarily because it is poor. He wants the best he can get for the money that he can afford to pay. It would be folly for any producer to raise raspberries that average 45 to the ounce when by a little closer pruning he could make them run 25 to the ounce, without any reduction in yield per acre. It would likewise be folly so to prune Concord grape vines that the juice tests 12 per cent sugar, if by a different practice he can make it test 15 per cent without an attendant decrease in yield. On the other hand, pruning may be a questionable practice if yield should decrease from 14 to 12 pounds per vine. The sweeter grape is the better grape, but unless those to whom it is sold so value this quality that they are willing to pay enough more a pound or a bushel to compensate for the difference in yield the practice is unprofitable.

The increasing resort of city families to apartment houses and the nearly universal installation of furnaces or steam-heating systems in family dwellings has resulted in either warm basements or none at all for a large part of the consuming public. With this transition the old practice of laying in a winter's supply of apples for the family has become almost obsolete. "Hand-to-mouth" buying has become the rule, with the grocery handling an increasing proportion of the family trade. Furthermore, a large proportion of grocers buy produce on a "hand-to-mouth" basis, never keeping more than a few bushels on hand, but requiring a constant supply. The fruit grower who hopes to sell direct to this trade can no longer sell off his whole crop by mid-November; he or the jobber must do the storing, since neither the consumer nor the grocer will do it. In northern states

the air-cooled storage is becoming an important adjunct to the orchard which supplies local markets. Many satisfactory houses of this sort have been built at a cost per bushel of storage capacity actually lower than a single season's storage charge in commercial warehouses.

Proximity to large cities has some disadvantages. As the city grows closer to the orchard, land values mount and with them the taxes. More important than this, the labor situation becomes difficult; the fruit grower must pay wages approximating those of the factory for labor that is likely to be unskilled, unreliable, and inconstant. If the business is particularly lucrative he will not be without local competition very long; in any case, as long as a railroad reaches his market he will have competition.

In spite of the difficulties, location close to the market offers unusual opportunities for men who are able to produce fruit well and sell it well; they can utilize both kinds of ability and often get a separate profit from each. They must have keenness to recognize changes, courage to depart from established principles and judgment to make these departures profitable; withal, they must have knowledge and initiative requisite to the production of high yields of good fruit, for this is essential to success in any kind of marketing.

CHAPTER XXII

ORCHARDING AS A BUSINESS

The fruit grower, like other farmers, receives no daily wage. He invests his money and operates his establishment in the expectation that at the end of the year or of a period of years it will reimburse him for operating expenses and upkeep, pay interest on and gradually retire the original investment, and still leave something for profit. In brief he is engaged in a business enterprise. His orchard must do more than furnish him employment, however congenial that employment may be. It must provide a living and it must be made to pay.

The difference between providing a living and paying is not merely rhetorical. Providing a living sometimes means that the orchard brings in enough returns to pay for spray materials, fertilizers, and fruit packages and to furnish the orchardist with shelter, clothing, and food so that he can go on losing money year after year. He is, in this case, paying himself wages for his labor but he is getting no interest on the money he has invested in the orchard and no profit from the business. His enterprise is comparable to a railroad which pays its employees, but defaults interest on its bonds and pays no dividends to its stockholders. The fact that in the orchard the capitalist and the laborer are one man does not lessen the obligation of the orchard to pay him wages, interest, and profit.

If ignorance is bliss, perhaps it is fortunate that many fruit growers do not analyze their businesses closely. Many a man has lived and died, raised a family and accumulated money, while growing fruit, in happy ignorance of the fact that he was not making money, as an auditor would view it. Nevertheless, most fruit growers can well afford to see their businesses as others see them, to study the various items of their expenses and to appraise them in terms of horticultural significance. Some which look large to the auditor may to the horticulturist seem small in proportion to their importance. At present nobody can say what is the proper balance between capital investment and oper-

ating expense in the orchard, but that wide disproportion exists and that redistribution would be profitable in many cases, cannot be doubted.

INVESTMENT COSTS AND DEPRECIATION

Logically and chronologically, land is the first item of expense involved in establishing an orchard. In a sense it is comparable

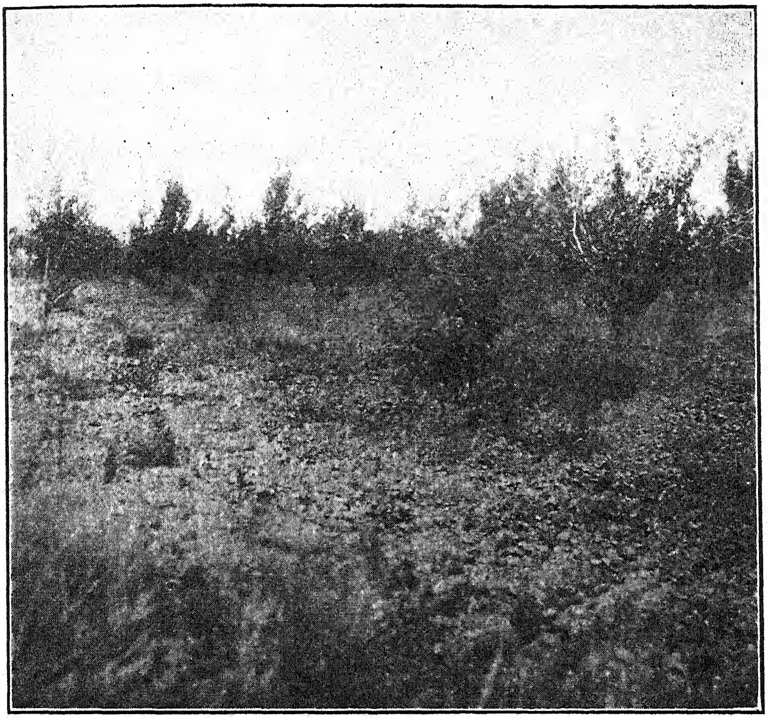


FIG. 132.—What was left, in 1926, of a pear orchard set on a poor site in 1909. Compare with Fig. 133, showing another orchard a scant mile away, planted at the same time and with the same varieties.

to the land on which manufacturing or shop-keeping establishments are located. Locating a shoe factory does not require close discrimination, provided it is accessible to transportation facilities and labor supply; the machinery functions anywhere. Locating a drug store or a cigar stand requires attention to little beyond the number, nature, and habits of passersby. In the first case site has little relation to the amount of business and with

a wide range of eligible spots the initial cost of the land becomes almost the prime consideration. In the second case location has important relation to the size of the business; eligible sites are few and the cost of land becomes secondary, though foot for foot it may exceed the cost of the shoe factory site many-fold.

FIG. 133.—A pear orchard set in 1909, on a good site. The picture was taken in 1926. Compare with Fig. 132, showing another orchard a scant mile away, planted at the same time and with the same varieties.

In locating the orchard the cost of land must be considered carefully. This constitutes a permanent capital investment on which interest and taxes must be paid every year, and any saving that can be effected in this outlay increases the amount that can be legitimately counted as profit. Price of land is determined by many considerations, some of which have no relation to productivity. Along the Missouri River some of the best orchard sites have sold for less than nearby bottom land or prairie farms, which are much less desirable for orchards, though better for

general farming. Similar conditions prevail elsewhere. Accessibility to centers of population raises the price of land without increasing its productivity and unless the orchard is to be also a shop for retailing fruit, the desirability of being "close in" must be balanced carefully against the permanent charge it entails.

Far more important than price, however, is the suitability of the land for raising fruit. Location has little conceivable effect on the way the machinery of a shoe factory works, but it has more effect than the fruit grower himself on the way that trees make apples, pears, or peaches.

The pear orchards shown in Figs. 132 and 133 were 17 years old when the photographs were taken. They were planted in the same year with trees of the same varieties, sizes, and grades, purchased from one nursery. They received almost identical management and the investment in them up to the time they were 7 years planted was practically the same. One of them bore a crop at this time and 10 years later was averaging 8 bushels to the tree while the other had yet to bear a commercial crop. Their divergence is attributable solely to the differences in site and soil. One orchard is on a slope lying well above a valley floor; its soil is deep, fertile, and well drained; the other is on the valley floor and its soil, though fully as fertile as the first, is poorly drained and has a high water table and in places is very shallow, with hardpan lying close to the surface. In this orchard stagnant water and summer drought have killed many trees, winter injury has taken many others and numerous replants have suffered the same fate. Few of the surviving trees are in good enough condition to pay for their own upkeep. The prices paid for the land were substantially the same, but the owners of the one were discriminating or lucky while the owners of the other relied too much on the universal applicability of the old notion that pears are tolerant of "wet feet."

Statistics on the causes of tree mortalities are not available, but a combination of circumstances sometimes permits a crude approximation. In 1910, Oregon had, according to the federal census, 2,029,913 apple trees of bearing age and 2,240,636 younger trees. In the ensuing 10 years all the trees reported in 1910 as not of bearing age should naturally have passed into the group of bearing trees; in addition the extensive plantings of 1911 and 1912 should have swelled the 1920 totals of trees of bearing age without having been recorded as young trees. Of

the older trees, undoubtedly some were removed because of "old age"—though the percentage of senile trees in Oregon in 1910 was very small—and removal of fillers and trees of unsuitable varieties accounted for some casualties. Even if it be conceded that these balanced the unrecorded plantings of 1911 and 1912, though actually they must have fallen far short of doing this, the total number of trees of bearing age in 1920 should have been at least 4,270,549; actually it was 3,315,093, leaving 955,256 trees—about 20,000 acres—among the missing. Other causes were operative, it is true, but the greater part of these missing trees must have gone out because they had been planted in locations defective in one respect or another. Many of the young trees of 1910 never reached bearing age and alfalfa now waves in the summer breezes over many a sunken orchard investment. This condition is not peculiar to Oregon. Montana had in 1920 only 53 per cent of the bearing trees promised in 1910; and the 1,059,198 trees bearing in 1920 had further dwindled to 686,505 in 1925; Colorado's orchards in 1920 contained but 49 per cent of the promise of 1910, and New Mexico's but 47 per cent. Eastern states show comparable shrinkages, but the influences operative there are more complicated because of the greater proportion of older orchards. In the western states the failures are due secondarily to economic mistakes and primarily to topographical sins. These trees were predestined to grievous days and untimely ends.

Besides the cost of the land, many items combine to constitute the capital investment. In the manufacturing establishment, labor and material expended in erecting buildings, installing machinery, roads, everything that is in place when the factory begins to manufacture, except the raw material, constitutes capital. In the orchard, the cost of the trees, labor expended in planting and caring for them, everything spent on them up to the time of bearing, together with expenditures on buildings and machinery, constitutes capital, on which interest must be paid until the original investment is retired out of the profits. In addition, interest on each year's expenditures up to the time of bearing becomes part of the capital. The aggregate capital invested in an orchard is more likely to exceed $500 per acre than it is to fall below that figure, except perhaps for peaches, because of their early bearing. That the owner has not paid out this sum at one time in cash, that he has "donated" his

labor, does not diminish the validity of the charge. He might have been earning wages by working elsewhere.

The two pear orchards used as illustrations of the importance of site, demonstrate another phase of orchard capitalization. When the one orchard began to bear, the investment in each was approximately $800 per acre. From that time the well-located orchard has been paying its current expenses, incurring no additional capital outlay on the trees, and paying interest on and retiring some of the original capital investment. During this same 10-year period the poorly located orchard has brought in little return and a large part of the running expenses, besides replanting costs, have been added to the capital; as a result at the end of this period the profitable orchard must pay interest on only about $500 per acre while the unprofitable orchard is now capitalized at almost $1,200 per acre. Were a miracle to happen in this orchard and half trees yield full crops, and pears spring out of dead stumps, it must nevertheless pay more than twice as much interest as the profitable orchard. Over-capitalization does not always consist in the original outlay; it often just begins at that time and sometimes it begins considerably later. Incidentally, this case throws some light on the notion of giving trees plenty of time to come into bearing, on the investment in late-bearing varieties, and on so pruning young trees as to delay fruiting.

Had this unprofitable orchard comprised but a few acres it would not have been a very serious matter. Actually it consisted of 125 acres and, at the time the photograph was taken, represented an investment of $150,000. Could blight have swept through and destroyed the orchard years ago it would have been a blessing in disguise for it would have put an end to the ever-mounting investment that thus far the owners have lacked courage to charge up to experience and write off as loss. The sum of $150,000 would build and equip a factory of fairly respectable size which could be the chief industry of a small town. Were such a factory to stand idle for years it would occasion no little questioning, especially if the management kept on putting money into it. Many orchards, however, present nearly this same situation, but it is less obvious, because so much of the expenditure is for labor and other items less tangible than bricks and machinery; it also leaves less for salvage and is more nearly a complete loss. Many other orchards

have incurred smaller deficits only because the proprietors reached the ends of their resources and were forced to abandon them earlier. Owners of many, many others are unfortunate in that their orchards were not quite poor enough to force their abandonment.

THE RELATION OF SITES, SOILS, AND YIELDS TO PRODUCTION COSTS

The more obvious losses of the trees that die and the orchards that are abandoned, however staggering their totals may be, are small in comparison with the tax levied by poor location and poor soil on the income from the great number of orchards that pay current expenses and, largely through ignorance of the real nature of production costs, are maintained at a loss. Within the period from 1921 to 1925 a block of 749 Duchess apple trees planted in 1904 in a Michigan orchard yielded an average of 3 bushels per tree each year. The trees were healthy and vigorous, but frost completely destroyed the crop in 1922 and again in 1924, and considerably reduced it in 1925. During the same period another orchard consisting of 200 Baldwin trees about 50 years old averaged less than 2 bushels per tree annually. Only 29 per cent of this fruit was large enough to meet A-grade specifications. In this case the site was almost ideal, but the soil was thin and infertile, unable to supply the nutrients required for heavy crops of large fruit. The trees themselves were more or less stunted, no larger at 50 years than apple trees should be at 20 years in good soil. Not far from these two orchards was another, also of Baldwin, 300 in number and 40 years old. During the same period, 1921 to 1925, it produced an annual return of over $400 per acre, while the older Baldwin orchard brought an annual return of $35 per acre. The 40-year-old Baldwin orchard received no better cultivation, spraying, or pruning than the other two; all three received good care. It is simply a better orchard, better because it is located on a site where freedom from frost made annual yields possible and because it has a soil on which trees grow vigorously. Liberal use of fertilizers might improve growth and yield in the 50-year-old Baldwin orchard and the use of orchard heaters might reduce somewhat the frost damage in the Duchess block but no treatment or combination of treatments could put them on a par with the Baldwin block that

averaged over 14 bushels to the tree annually through the entire 5-year period without orchard heaters. Cultivation, fertilizer, spraying, pruning, supervision and other current maintenance costs together in all three orchards probably range between $40 and $50 per acre annually. Insurance, taxes, interest on investment, and other overhead charges increase this amount considerably. This Duchess orchard has been a liability for 21 years, the one Baldwin orchard for 50 years, ever since the trees were planted. Both will continue to be liabilities as long as the trees live, for neither can be made to yield profitable crops over a term of years. Though these three orchards, located within a few miles of one another, present rather extreme conditions, they illustrate conditions that prevail widely in various degrees, often unsuspected.

The comparative permanence of capital charges enhances the importance of keeping them down to the lowest point consonant with the development of a good orchard. At the same time full recognition must be given the great saving in operating expense sometimes effected by a comparatively small capital outlay. The fruit grower in his capacity as orchard manager may have to persuade himself as auditor that the expenditure of $300 or $400 on improving the water supply will cut from the cost of spraying more than the amount of the interest incurred and perhaps return the whole cost by the better protection given a single crop. The curve of compound interest, however, should teach the wisdom of deferring capital expenditure until it is needed. Erection of a packing shed long before there is something to be packed adds needlessly to the capital charges.

However the items constituting capital investment may vary, the one item generally recognized in any enumeration of them, namely land, actually constitutes but a small portion of the total. Ordinarily it does not amount to one-fourth; if it does, the land has cost too much or the orchard has been slighted. Upon this fractional part of the capital investment more than on any other part of orchard expense depends success or failure of the whole investment. Selection of land is not ordinarily a matter of price, since in most sections good orchard locations cost little or no more than poor locations. It is ordinarily a matter of discrimination between tracts costing approximately the same, though it is not the place to begrudge a few dollars.

VARIETY MAY "MAKE" OR "BREAK" A GROWER

If the factory finds itself producing an article for which there is no longer a demand it can shut down, eliminating virtually all running expense, until the demand returns, or it can give its employes a week's vacation—without pay—and in that time install new machinery for turning out an article toward which fashion's caprice is favorable. When the fruit grower finds his orchard in comparable condition, *i.e.*, if the varieties it produces are permanently unsalable or unprofitable, his problem is, in many ways, more serious; certainly his readjustments take more time and ultimately they probably involve relatively higher expense. He must stop production without at the same time being able materially to curtail running expenses; he must pull the trees out and replant or he must top-work them and wait 4 or 5 years for the new crop. He should guess right at the beginning.

Site and soil, important as they are, are not the sole factors producing differences in returns. The varieties grown may assume equal importance, for the best of soil cannot make a poor apple good, or a low-yielding variety fruitful. The Crawford peach has given way to the Elberta in commercial plantations principally because of low yield. The Ben Davis apple occupied the place it did because of the crops the tree bears, certainly not because of the quality of its fruit. In one Michigan orchard for which records are available, Early Richmond cherry trees averaged 2,489 pounds per acre annually for a 7-year period beginning in their ninth year while Montmorency trees of the same age in the same orchard averaged 14,380 pounds. Both varieties were sold to the cannery at the same price per pound. The returns received for the one variety barely covered production and harvesting costs; those for the other netted a substantial profit. In the same orchard and during the same period mature trees of Windsor and Schmidt (sweet) cherries yielded a marketable grade of fruit at a rate that made their production cost 5½ cents per pound; Lambert (largely because of fruit splitting) yielded a marketable product at a rate that made its production cost 19 cents per pound. With an average selling price of 9½ cents per pound for all three varieties the owner had to sell 2 pounds of Windsors and Schmidts to make up for the loss on each pound of Lamberts.

Varieties, however, are not to be rated entirely on the basis of yield. Earliness of bearing, longevity, relative susceptibility to

insects and diseases, the way in which the fruit grades out, market demand and price should all receive due consideration. The Flemish Beauty pear is surpassed in quality by but few varieties and high-grade fruit of that variety commands relatively high prices, but the variety does not find favor with most growers because of its extreme susceptibility to scab. Many Georgia peach growers have found Mayflower and Arp Beauty relatively more profitable at $3.50 per crate than the better Hiley and Elberta at $2 per crate because they mature 2 weeks earlier when supplies are lighter and demand keener. At its best Yellow Bellflower is a good apple, but in one long-period test it was found to yield only 37 per cent A's. Furthermore, by the time this apple reaches the retail stand, it always shows handling bruises that did not appear as it passed over the grading table, the result being that some other variety is chosen. Figures show that over a period of years in Michigan the Sweet Bough apple has sold for 35 cents more per bushel than the average for all other varieties. It would be unwise, however, to make extensive plantings of this variety because its season is short and the demand very limited. The case is comparable to situations found in all lines of business. Clock makers manufacture a few "grandfather" clocks and sell them at a profit but they can do a larger volume of business and in the end make greater profit with the more common "alarm" variety. The 5-year average selling price for A-grade fruit of the best ten apple varieties handled by a Michigan cooperative marketing organization was $1.60 per bushel; for their poorest 10 varieties it was $1.08. This organization handled 4,120 bushels of A-grade fruit for one of its members during the 5-year period, for which it paid him $6,280; for another member during the same period it handled 4,328 bushels of the same average grade, but of different varieties. His receipts totaled $4,475.80. That difference of $1,500 was the penalty this man, fully as capable and industrious, paid for putting his trust in the wrong nursery salesman, for betting on the wrong varieties.

OPERATING EXPENSES

Operating expenses begin when fruit production begins. Spraying, cultivation, fertilization, any or all of which were formerly charged against investment, now become operating expenses, to be paid from the proceeds of fruit sales. Harvesting

charges and cost of packages, the most cheerfully paid of all items, are welcome additions to the operating expenses. Less obvious but none the less real are tolls levied by time and wear and chargeable as depreciation or in part as amortization. This item applies alike to buildings, equipment, and the trees themselves; it is of course greater when the effective lives of materials and trees are short. In addition, the orchardist may legitimately pay himself something for his services as expert director of the enterprise in addition to such wages as he may earn.

The relentlessness with which a large portion of the operating expenses accumulates, regardless of the size of the crop, emphasizes the importance of having no crop failures; this, too, is largely a matter of having a good location. A raspberry grower once jocosely remarked that he expected to lose less money than he had the year before because he should have fewer berries to sell. He actually sold 428 crates, at an average price of $2.24 per crate. This crop was raised on 8 acres; charges for fertilizers, interest, taxes and insurance, pruning, hoeing, cultivation and spraying, depreciation and supervision, amounted to $376; harvesting costs aggregated $232. His net profit was 80 cents a crate, or $44 per acre. One of his neighbors, from a 10-acre plantation on poorer land harvested only 217 crates, because of some frost injury, an incomplete stand of plants, presence of disease, and a droughty soil. His production costs per acre were the same as the first man's ($47) since his taxes were as high, depreciation of plantation even more rapid, and care of the soil equally expensive. Harvesting costs were naturally less per acre, but about the same per crate. He spent $470 growing his crop and $118 harvesting and selling it, a total of $588. For his 217 crates, sold through the same trade channel and at the same price as his neighbor's berries, he received $486. His net loss on the season's operation was over $100, nearly 50 cents per crate. Had the crop been a total failure he would have lost still more because production costs would have remained the same and every crate harvested and sold reduced the total net loss on the entire crop. Had this grower been able to sell his crop for $2.71 per crate instead of $2.24 he would at least have come out even on the season's operations, but, as is usually the case, he had practically no control over market conditions, and was forced to sell at prevailing prices. It should not be overlooked, however, that had his acre yield equalled that of the

8-acre field, he would have made the same profit, $44 per acre or 80 cents per crate, at the actual prices. Until fruit sells for less than the harvesting cost, every package marketed cuts down losses, even though each package is sold for less than the cost of production. On an acre basis harvesting costs increase with the crop, while the other operating costs are practically stationary; computed in terms of yield, harvesting costs remain practically stationary while "other" operating costs decrease. For this reason, when "other" operating charges are high in proportion to harvesting costs, the change from loss to profit—or in the other direction—occurs rapidly.

All in all, operating expenses constitute a formidable array. Some of them vary with the size of the crop; others—generally aggregating more than half—are constant. Occasionally the most effective reduction in operating costs is achieved by additional capital investment. Skilful management can reduce some items but short-sighted economy is likely to increase the larger portion—the constant charges—by decreasing the yield. Inclination to cut expenses generally fastens itself to items involving cash outlay, because they are more obvious, though they are often smaller than the "invisible" charges. In many cases the items on which economy is attempted constitute but a small portion of the total expense and are withal disproportionately important to the value of the crop. Spraying materials and fertilizers are likely to fall into this category.

PRICES AND WHAT MAKES THEM

As an auditor would view an orchard business, receipts must pay operating expenses, interest on the investment, and they must ultimately retire the capital. After this is done the surplus may be regarded as profit and the orchard be considered truly profitable, though it may be remarked that from the sociologist's point of view the owner can be reasonably well off even though his orchard is not profitable, provided it is not unprofitable. Be that as it may, expenses, living, interest, and profit must come out of receipts, which are the product of two variables, yield and prices. Therefore the grower is not to be blamed if his interest is keener in prices than it is in expenses. Prices always arouse the speculative interest; they are obvious and an unskilful, lazy man can make money from a poor orchard if prices go high enough.

Producers generally hold the opinion that profit depends first, last, and all the time on price. In this they are undoubtedly correct. Unless fruit can be sold for more than its cost of production the enterprise is doomed to failure and, just as certainly, profits mount only as the margin widens between production costs and selling prices. It is for this reason that great attention has been devoted to the study of distribution and to the trial of new marketing methods. This idea, with that of price fixing, lies at the bottom of the movement for cooperative selling. No matter how attractive the idea of price fixing may be, it is obviously impracticable, if not impossible, with commodities such as fruits, which are not absolutely indispensable and whose production is in the hands of many thousands of people scattered over a wide territory and free to act independently of one another. Under these circumstances prices are fixed by supply and demand, rather than by agreement, volition, or cost of production. In commodities such as fruits, the interacting forces really number three, because price regulates demand as much as demand affects price. Being unable to control two of these variables producers can hardly expect to control the third. Whether the producer likes it or not makes little difference; he may as well recognize the situation and adjust his business accordingly.

In one sense, then, price is not determined by the producer; he must sell for what the trade offers or not at all. In another sense, the price he receives is to a considerable extent under the individual grower's control, for it depends largely on grade, which in turn is determined chiefly by the way the grower raises, harvests, and handles his fruit. The average price that a Wenatchee (Washington) shipping organization received for its Extra Fancy grade Winesap apples in 1925 was $1.57 per box; for its Fancy grade it received $1.32, for its Choice grade $0.96 and for the culls $0.22. In Michigan the 5-year average prices per bushel received for all apple varieties by a group of shipping associations were: for A-grade $1.29; B-grade, $0.93; culls $0.22. The crops of a member of one of these organizations graded out 24 per cent A, 12 per cent B, and 64 per cent cull, "bulk" and "canner" stock. For his entire crop he received an average price of 58 cents per bushel. One of his neighbors produced a crop that graded out 82 per cent A and 12 per cent B; his average return per bushel was $1.12. The 58 cent price left little margin above production costs, if indeed it equaled them, while the

$1.12 price certainly left some margin. These two growers were paid the same price for their fruit, since it was delivered to the same packing shed, graded and packed by the same crew, and sold by the same sales manager to the same buyer, yet one received nearly twice as much per bushel as the other. The main reason for the difference in price was the enterprise of the one man and the negligence of the other.

The price differentials between grades, which hold for nearly all fruits, are far greater than most of those due to differences in marketing methods or machinery. They are greater than most of the differences between averages in years of low and those in years of high prices, and greater than any of the differences between years of medium and years of extreme prices. Therefore it may be said that in large measure prices are within the grower's control.

THE FACTORS THAT INFLUENCE PRICE THROUGH DETERMINING GRADE

The various factors that lead to the grading down of fruit naturally vary with the kind and variety of fruit and with growing conditions. In the case just cited, where only 24 per cent of the crop was A-grade, 34 per cent of the culling was due to deficiency in size, 25 per cent to insect injury, and 15 per cent was necessitated by handling bruises. Only 26 per cent was due to hail, limb rub, sunscald, and other more or less unavoidable troubles. That handling bruises are due to carelessness and are almost entirely preventable is obvious. That insect and fungus injuries are under control to an almost equal extent is demonstrated by the fact that though 17 per cent of this grower's apples were scabby, less than one half of 1 per cent of his neighbor's fruit of the same varieties was graded down because of this defect. Both orchards were sprayed with the same materials and received the same number of applications. The real difference between the two spraying treatments lies in the fact that one man used a little more material to the tree and was more careful in timing his applications. Though he got better results, his spraying costs were little higher than those of his less efficient neighbor; they were respectively 39 and 31 cents per tree for the season. Conservatively figured, that extra 8 cents returned over $2 because of the higher prices received for the better grades of fruit. This was an unfortunate cut in operating costs.

Size of fruit is to a considerable degree likewise under the grower's control. Figure 134 shows peaches from trees alike in variety and age, cultivation, and spraying, but receiving different pruning, fertilization, and thinning treatments. Those in the top row were taken from trees unpruned, unfertilized, and

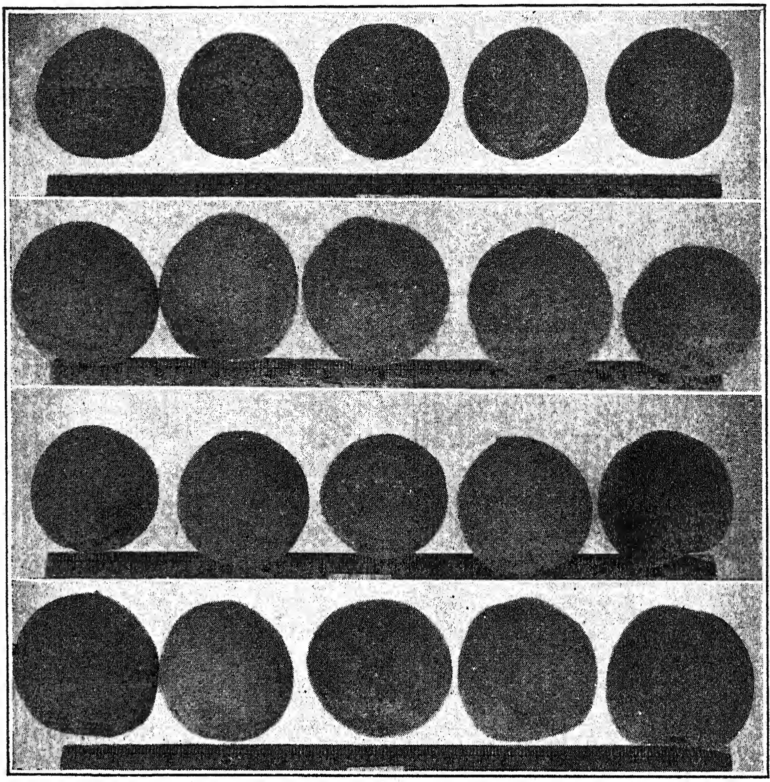


FIG. 134.—The peaches in the top row were from unpruned, unfertilized, and unthinned, though well cultivated, 16-year-old trees growing in good soil. The effects (on size) of pruning, of thinning, and of pruning, thinning, and fertilizing combined, respectively, are shown in the second, third, and fourth rows.

unthinned, while those in the second row came from trees heavily pruned. The third row shows specimens from trees that had not been pruned or fertilized but whose crop had been thinned. The fourth row was taken from trees receiving pruning, fertilizing, and thinning. The top row in Fig. 135 shows pears grown with abundant water; the lower row shows specimens from

trees scantily supplied. Black raspberries harvested from short-pruned canes and averaging 20 to 25 to the ounce find a ready sale, when berries produced on long-pruned canes and averaging 35 to 40 to the ounce move slowly and at a much lower price. Various practices influence size, some of them rather directly, others more indirectly through the soil. In general, those that operate through the soil tend to increase yield at the same time that they increase size, while pruning and thinning effect an

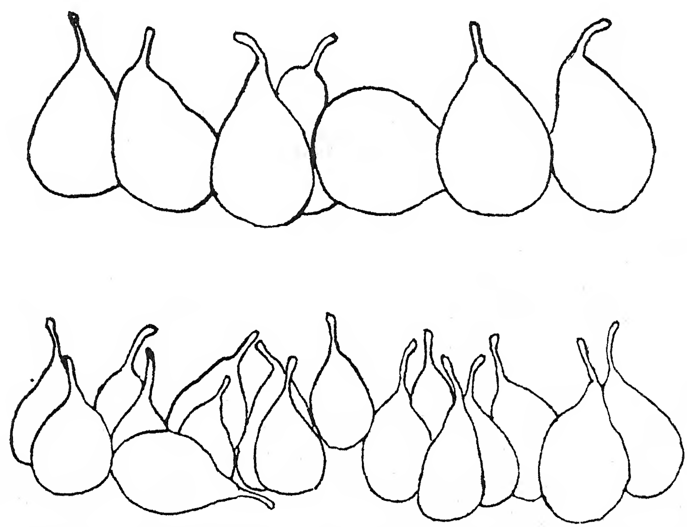


Fig. 135.—Comparative sizes of Bartlett pears produced on trees supplied liberally (above) and scantily (below) with irrigation water. (*After Barss.*)

increase in size through a reduction in number of fruits, and frequently in total yield. All of them influence price, income, and profits. Decision as to the method or combination of methods which is most practicable in any particular instance and as to the size which is desirable, varies with circumstances and often requires the exercise of keen judgment. The premium paid for large size varies and the method or procedure best suited to one fruit crop or age of tree may not be best suited to another, even on the same farm. There is no question, however, but that more fruits find their way into the cull pile or the lower grades and that growers experience greater losses on the fruit actually produced because of small size than because of any other one deficiency.

Besides watching the fruit, the orchardist must watch the men handling it. Unlike deciduous fruits, oranges and lemons are clipped from the trees with shears, leaving attached to each fruit a short piece of stem. This prevents the decay that would almost certainly set in were the fruits pulled from the trees leaving exposed some more or less torn tissues. If the stem is left too long it is likely to bruise or puncture other fruits on the packing table or in the crate; when it is cut too short the scissors may cut into the surrounding flesh or peel, thus ruining the fruit for long storage or distant shipment. One large lemon ranch was having what its manager considered excessive loss from decay in its shipments. Investigation showed that in a large percentage of the cases the decay organisms had entered the fruit through punctures and that 15 to 20 per cent of the fruits gathered by some pickers showed scissors cuts or dangerously long stems, while less than 2 per cent of those gathered by other employees showed these injuries. This information enabled the manager to reduce the losses from decay to less than one-fifth of their earlier proportions. Losses occasioned by handling injuries are even more serious with peaches and apples than they are with lemons, and they are equally avoidable.

Champion apple pickers generally cost their employers far more than their wages, for in this work haste literally makes waste. Many apple growers find profit in paying pickers by the day rather than by the bushel, since this practice, though it generally increases the total picking cost, decreases the percentage of culls and decreases the cost of picking A- and B-grade fruits. Harvesting apples by shaking and beating the fruit from the trees would be the most expensive method possible, unless the fruit were worth very little indeed.

CULTURAL TREATMENTS AND YIELD

Yield is determined first by site, second by soil and third by variety, matters rather well settled for the life of the orchard once it is planted—in brief by the nature of the original investment. Nevertheless, yield can be influenced to a marked degree by certain cultural treatments—by the way the investment is guarded. Lack of skill can make the best located orchard unprofitable and recognition of weakness inherent in any location or soil can aid in overcoming some difficulties. The effects of cultural practices on yield should not need restatement at

this point, unless it be from the auditor's point of view. Figure 136 shows two rows of 14-year-old Montmorency cherry trees, growing in a light sandy soil in a Michigan orchard and treated alike except that for 4 years each tree in one row had received annual applications of 3 pounds of sulphate of ammonia; 10 cents added to annual operating expenses for this fertilizer returned approximately $3.91 in increased yield. Computed on the basis of cost per pound of fruit produced, all the operating costs except harvesting were cut by this outlay.

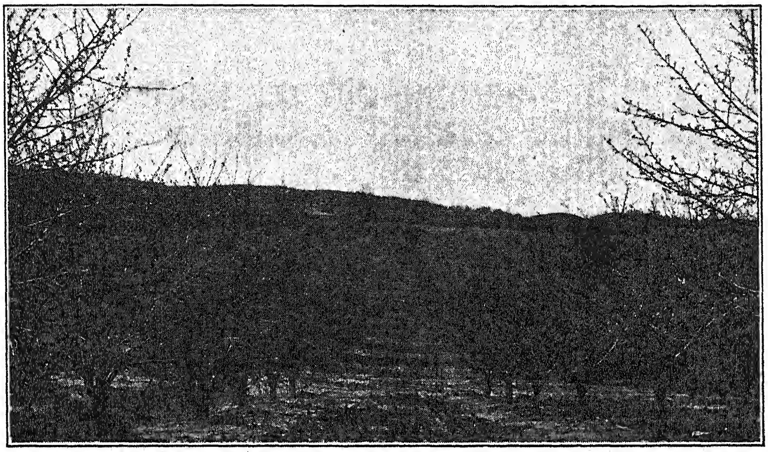


FIG. 136.—Two rows of Montmorency cherry trees. That on the left has received annual applications of nitrogen-containing fertilizers; that on the right has not been fertilized. There is a three to one difference in their average yields.

The emphasis placed upon the almost irrevocable nature of the commitment involved in locating an orchard and the enduring influence of the site must not obscure the need of knowledge and initiative in its manager. Location limits the possibilities of an orchard; management realizes them. Realization of possibilities, however, is attained only by unremitting diligence and watchfulness. The well-located orchard is not a bond which automatically yields interest-bearing coupons at regular intervals and is left to accumulate dust between these intervals. It is, in one sense, more like a manufacturing establishment constantly appreciating or depreciating in value, depending principally on the ability and judgment of the executive, the skill of the employees and the nature and quality of its output.

THE SITUATION SUMMARIZED

In commercial fruit production the one constant aim should be to widen the margin between income and outgo, between production costs and selling prices, since profits lie within this margin. For a given kind of fruit and within any given district, or even region, comparatively little can be done to reduce production costs per unit of cultivated land. The cost of land, spraying, pruning and other cultural treatments and the overhead charges after all vary only within comparatively narrow limits, if the orchard is well managed. There is an enormous variation in production costs per unit of fruit produced, however, low costs being associated with heavy yields and high costs with low yields. The key to low production costs therefore is heavy yields. In most cases yield depends on site, soil, variety, and soil management methods, in the order named. These factors are under the individual grower's control, in part at the time he sets his trees, in part later. Beyond certain limits the individual producer has no control over prices. They are established by general trade conditions. Within those limits, however, he has fairly complete control, through his control of grade. Improvement in grade may often result in what amounts to a doubling of price and the multiplying of profits many times. With most fruits and most conditions, soils and soil management methods tending to promote better size, spraying to control pests, care in harvesting to avoid handling bruises, and pruning and thinning, likewise to improve size, are, in the order named, the important factors in controlling grade.

In comparison with most types of agricultural effort, fruit growing is intensive. The capital investment per acre is comparatively large and interest and much of the maintenance expense go on regardless of crop failures. In proportion to the value of good fruit crops, the charges per acre are perhaps rather low. Fruit growers, therefore, can lose money or make money faster than most farmers, depending on the number of crop failures, and since prices are highest in years of rather general failures, the orchards which "always" have crops are particularly profitable. Despite the occasional narrowness of the margin between heavy crops and crop failures and despite the fluctuations in prices, fruit growing is essentially not a speculative enterprise. Its profits are measured in long-term averages and weeding out of the conspicuously unfit and highly speculative is unrelenting.

This fact, with the deferred maturity of the investment, tends to keep out the gamblers, the "in-and-outers," and the "shoe-string operators,"—or at least they do not remain in it long—and it tends to keep fruit growing preponderantly in the hands of enlightened, far-seeing, conservative men.

Samuel Hartlib, an interesting member of an interesting group, wrote, at the middle of the seventeenth century, concerning orchards:

> They afford curious walks, food for cattle in spring, summer and winter, fuel for the fire, shade from the heat, physick for the sick, refreshment for the sound, plenty of food for man, and that not of the worst, and drink also of the best, and all this without much labour, care, or cost.

This Polish-English merchant and philanthropist lived over a century before John Stuart Mill first formulated an organized body of economic thought and considerably over two centuries before the rise of the cost accountant and it is doubtful whether he or any of his contemporaries thought correctly in estimating costs. In his time, fruit growing was reputed to be exceedingly profitable, because prices of fruit were relatively high, and much of the expense of producing it, involving no cash outlay, was unsuspected. Even with this allowance, however, it seems safe to say that the trend in fruit growing has been toward a narrower margin of profit, with a larger volume of business and that the tendency has been to increase the proportion of capital investment to operating expenses.

People have learned to look elsewhere than the orchard for medicine, drink, and fuel, or for pasturage and shelter for their cattle; they no longer walk for pleasure, but never before has there been such extensive specialization in fruit growing for profit. Fruit production is no longer, if indeed it ever was, a field for the invalid, the ne'er-do-well, the family dullard, the remittance man, the sentimental faddist, or any sort of dilettante; it is a business demanding the same acumen, initiative, and devotion that any other business requires. That on the whole its results are satisfactory is attested by the fact that the fruit growers of the nation constitute a large body of intelligent and capable men who appear to have found no more attractive field for their efforts.

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